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# Growth Rate Assessment of Alcyonacean *Sarcophyton glaucum* from Northern Hurghada, Red Sea, Egypt

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## Abstract

Eighteen specimens of the soft coral *Sarcophyton glaucum* have been collected and tagged to determine the growth rate using the weight variations technique and to investigate the reproductive season histologically. Six colonies were totally weighed and 12 fragments (produced from three colonies) were marked and weighed. Some samples showed sever shrinkage that lead to death. The maximum semiannual growth rate was recorded in summer (30.05 gm/6 m). The average monthly growth reached 3.95 gm/month. Many factors affect the growth rate such as water currents, turbidity, sedimentation, temperature and reproduction process. The studied species is a dioecious species (unisex), where the Autozooid polyps are the reproductive organs while siphonozooids are sterile. Female gonads were observed to develop at late July before male gonads which began at late September. Larvae releasing started at late January and the gonads are completely spawned in February. Fertilization occurs internally to form planulae larvae which librated completely in February. The oogenesis exhibited prolonged about 23 months, which gave rise to oocytes of different developmental stages in female colonies at any given time, and a spermatogenic cycle of only 10 - 12 months.

## Keywords

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## 1. Introduction

The growth rate of family Alcyoniidae has been avoided by most researchers due to the softness of the coral animal and difficulties in the determination of growth. Very few investigations were related to the reproduction of soft corals in the Red Sea and not concerned with their growth rates; this action makes a gap in their biology, especially with regard to the sexual reproduction. So, the present study investigates the growth rate of *Sarcophyton glaucum* and its effect on the reproduction process. On the other hand, high growth rates of asexual reproduction were found in the Red Sea *Xenia macrospiculata* by Benayahu and Loya [1]. The radial growth was determined in both *Sinularia* and *Sarcophyton* which reached about 0.5 cm·yr$^{-1}$. *Sarcophyton* compensate for their low rates of reproduction by having low mortality and living to a great age [2]. Some soft corals display opportunistic life history features such as fast growth rates, high fecundity and asexual reproduction [3].

Some studies have focused on planulating species of the family Xeniidae [1] [4]. Among members of the family Alcyoniidae several modes of sexual reproduction have been recorded. The temperate species *Alcyonium digitatum* releases gametes and *A. hibernicum* has internal parthenogenesis of planular development; although alcyoniids are very common on coral reefs, little is known about their sexual reproduction and gonadal development. Yamazato [5] present circumstantial evidence for gamete spawning in *Lobophytum crassum*, and an external mode of planular brooding was described in the alcyoniid *Parerythropodiumfulvumfulvum* [6]. Moreover, recently spawned eggs were collected from several alcyoniids in the Great Barrier Reef, Australia [7]. *Sarcophyton glaucum* is one of the most conspicuous alcyoniids on the Red Sea reefs and at numerous sites across the Indo-West Pacific Ocean [8] [9].

Benayahu and Loya [10] examined various aspects of sexual reproduction in *S. glaucum* and presented the annual gonadal development, mode of reproduction, and its annual duration with their synchronous. However, this species illustrated a relatively high survival rate especially for the produced fragments [11]. On the other hand, there are many factors could affect the growth as temperature, sedimentation, turbidity and water motion [12] as well as the light intensity, salinity and feeding regimes which affect the survival rate [13]. Chavanich [14] pointed out that the elevated temperature appeared to be a more powerful causative factor than salinity on the survivorship especially during the extremely low tides (at June). In addition, the Antrophogenic factors such as catchment uses, unsustainable and destructive fishing may cause coral reefs degradation [15].

Cultured corals are known to be highly prized for three main markets: a) the bioprospecting of natural products for the pharmacological and biomedical applications [16] [17]; b) the marine aquarium trade [18]; and c) coral reef restoration efforts [19] [20]. These cultured corals were influenced by numerous factors, such as water movement [21], temperature [13], and light [22] [23]. While the *ex situ* culture of corals involves higher production costs, it has the advantage of maximizing survival and growth rates through the optimization of culture conditions [24]. The aims of the current study were: i) to assess and determine the growth rate using the weight variations technique underwater for the most common soft coral *S. glaucum*; ii) to determine the survival rate of the whole colonies and the fragmented pieces and their growth rates; and iii) to investigate the reproductive season histologically.

## 2. Materials and Methods

### 2.1. Area of Study

The studied area in front of the National Institute of Oceanography and Fisheries (NIOF formally mentioned Marine Biological Station, MBS) was chosen due to its naturally protected area from most of the anthropogenic, human activities and the diving and/or the fishing processes. It is also not affect by any anthropogenic impacts or any human activities but affected by sedimentation processes due to the water movements and the north coming currents. The studied site is located at 5 km north Hurghada City (**Figure 1**) at latitudes of 27°17'13"N and longitudes of 33°46'43"E, where it is characterized by high sedimentation rates [25]-[27].

### 2.2. Methods

Some physical factors, as temperature (°C), salinity (‰), PH and dissolved oxygen (mg·l$^{-1}$) were measured as averages for one year at each site and were measured seasonal mean at the studied site using Hydrolab instrument (Model Surveyor 4, 1997).

**Figure 1.** The location map of National Institute of Oceanography and Fisheries (Marine Biological Station MBS).

## 2.3. Growth Rate and Reproduction Determination

Nine colonies were chosen for studying the growth rate. Six colonies were totally weighing according to weighing technique of Bake [28]; the other three colonies were fragmented into 12 fragments (see **Figure 2**) according to the fragmentation technique of English [29] which were applied using a pair of stainless steel scissors for the semiannual measurements of the increase in growth rate. The present method modify Back's method using weighing technique which was used for the whole six colonies by underwater weighing scale in grams and milligrams. This technique was applied due to the irregular shape of the coral colonies and its great sensitivity for losing water which cause shrinkage and death of the colony [30].

The fragments were dipped in fine sediments immediately after cutting; this helps to seal the exposed area to prevent the loss of the animal fluid, and adds negative buoyancy to the cut area of fragment [30]. Before weighing process, the particulate matter and sediment are cleaned carefully to avoid error in measurements (balance standard error is ±0.1 during weighing) and avoid any damage for the coral. The coral fragments were weighed separately before planting, to avoid water loss. Sample was placed in a tumbler filled with known weight of water, then by the calculating the difference between the weight of the tumbler with water and the weight of the tumbler containing water and sample. So, we determined the sample weight without water loss.

After the weighing process, coral fragments are fixed on plastic plates using a thin wire (or pike tooth) by piercing through the part, then marked and tagged for the following stages. Then the coral samples were placed in the sea at protected area from turbulence at 5 m depth, so the site should be chosen primarily for low turbulence and care must be taken to protect the corals during the attachment phase. After two weeks the thin wire removed and the fragments became attached well with the substrate and then samples weighing again. The growth rates for the coral fragments and the whole colonies were determined and measured semiannually (twice per year; once each six months due to the colonies sensitivity and to avoid the colonies shrinkage and death) at the warm season (summer) and the cold season (winter).

Some the expanded and relaxed polyps were collected immersed rapidly in 10% formalin solution for the histological study. Some polyps were fixed in Bouin's fluid, and then were decalcified within a solution of formic acid and sodium citrate for about 15 - 20 minutes according to Rinkevich and Loya [31] for the following steps of histology and examinations [25]. The gained planulae larvae were examined microscopically and amplified up to ×400. The sectioned tissues were examined under the stereo binocular microscope and then photographed using microscopic camera. The gonads size was measured by eyepiece micrometer. Camera Lucida was used to draw the sections.

## 3. Results

### 3.1. Growth Rate

The preliminary weights of the whole six colonies and the twelve fragments were determined before planting and reweight again throughout a year for determination of the growth rate. However, the maximum growth in the whole or the naturally grown colony reached 30.05 gm/6 month in summer and the least growth reached
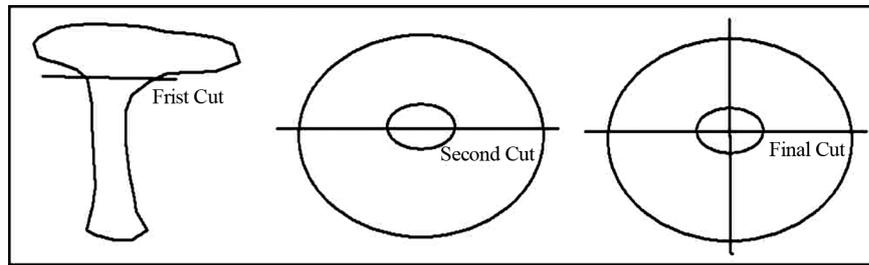
**Figure 2.** The fragmentation method of the selected colonies of *S. glaucum*.

20.15 gm/6 month, while in winter the range of growth was varied between 21.04 - 28.36 gm/6 month (**Figure 3**). On the other hand, the transplanted fragments grow with sub-equal values or slightly lower. They recorded a range of 19.20 - 29.70 gm/6 months in summer and a range of 18.50 - 29.30 gm/6 months (**Figure 3**).

The average semiannual growth of the naturally growing colonies recorded the highest value (25.875 ± 1.4058 gm/6 m) in summer; while in winter they illustrated a slightly low value (23.533 ± 1.2018 gm/6 months). While the coral fragments illustrated lower average than the natural grown colonies but appeared as sub-equal values in both summer and winter. The average growth recorded 23.483 ± 0.9171 gm/6 m and 23.083 ± 1.001 gm/6 m in summer and winter respectively (**Table 1**). Moreover, the average annual growth rates of the natural growing colonies recorded a relatively higher rate, 49.408 ± 2.4105 gm/y, than the fragmented colonies which reached 46.567 ± 1.9094 gm/y (**Table 1** and **Figure 4**).

One-way ANOVA indicated that, there is no significant difference between the recorded data of the growth rate of the coral fragments during the first six months (during summer) and second six months (during winter) at P-value = 0.205 > 0.05 (**Table 2**). Moreover, the survival rate of the used colonies (n = 12 fragments and n = 6 small colonies) were approximately 100%.

## 3.2. Gonads Formation, Position and Sex Determination

The colony contains numerous dimorphism polyps (the **autozooids** and the **siphonozooids**) (see **Figure 5**). The **autozooids** (reproductive organs-carriers) appeared during the protrusion and extension outside the colony ground (**Figure 6(a)** and **Figure 6(c)**). It reached to 8 - 9 mm length and 0.8 to 0.9 mm base diameter. The **siphonozooids** appeared as minute dots scattered between the autozooids (**Figure 6(c)**). It is obviously noticed that, the water lose of the colony occurred through the siphonozooids. The autozooids have a cylindrical shape body opened with a mouth opening which is surrounded by few numbers of tiny tentacles (always 8 tentacles). The whole colony (stalk, disc and polyps, in the surface or in the coenenchyme) has calcium carbonate spicules (**Figure 6(b)**), which help in identifying the species and give the colony its internal skeleton.

The autozooids is a tube differentiated morphologically into three main regions: the main body (anthocodial stem), the oral disc and the tentacles. The autozooids are communicating by means of transverse tubes through the coenenchyme of the colony; these tubes are composed mainly of the continuation of the gastro vascular cells, which help in the asexual reproduction and developing the new polyps.

**Gonads:**

The gonads, either male (in the male colonies) or female gonads (in the female colonies), were found and formed in the second half of the autozooid length on the mesenteries and never extending upward to the oral disc or to the base of tentacles, while the siphonozooids have no gonads. The gonads start their development from the cells of the endoderm of the mesenteries (the interstitial cells) it begins by minute swollen where it divide into a series of independent pieces and form a row of globular structure until it ripe and swell from the mesenteries to be differentiated into one large eggs or sacs of spemaries. The size of gonads varied with the size of the colony size, the male gonads in mature stage ranged in general between 500 and 600 µm, while the female gonads diameter in mature stage ranged between 400 and 450 µm.

The eight septa or the mesenteries of the autozooid that are attaching to the endoderm layer of the Actinopharynx (stomodaeum) and extending to the base of the autozooid are consisting of three layers; two outer endodermic layers and an inner mesogloea layer. There are primordial generative cells developed in the endoderm of the ventral and lateral mesenteries in the mesenteric chambers and may migrate to the mesogloea during the early development of the genital cells.
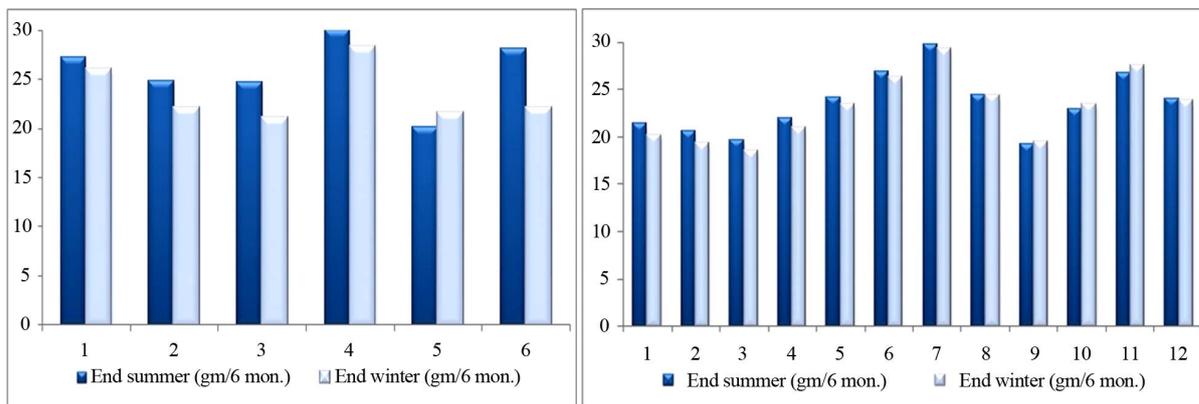
**Figure 3.** The six natural growing colonies (left) and the twelve fragments (right).
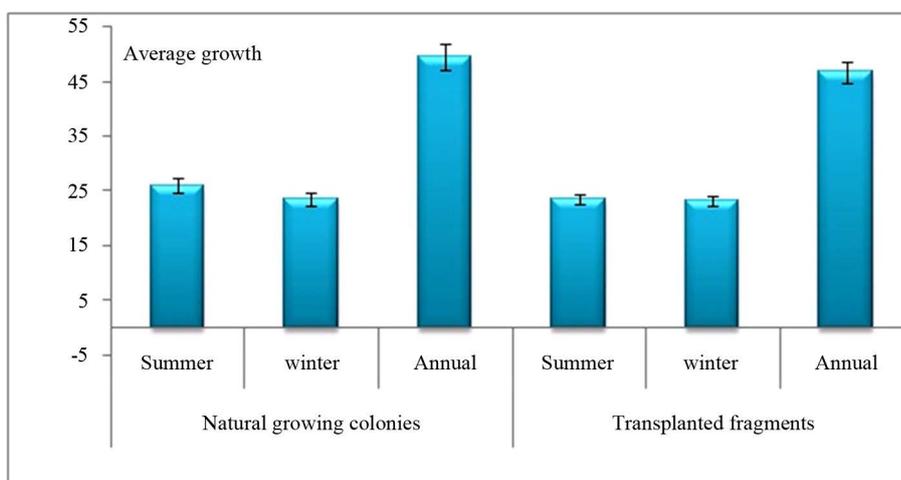


**Figure 4.** The average semiannual and annual growth of the natural and fragmented colonies.



**Figure 5.** Fragmented colony (left) and the natural grown colony (right).

**Table 1.** The average and range of the whole and the fragmented colonies through a year.

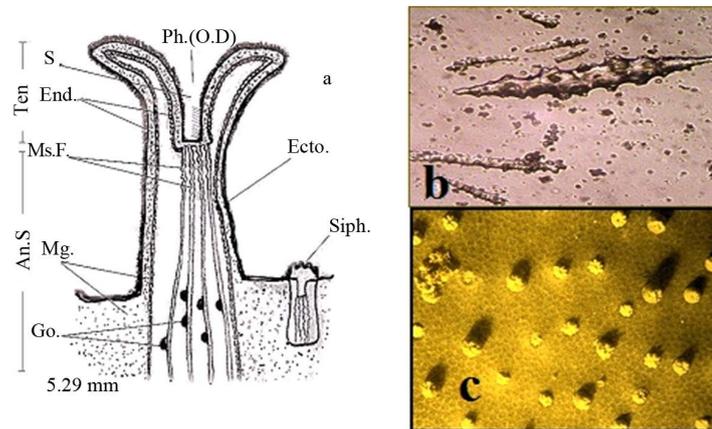| Categories | Type of Growth | Summer | Winter | Annual |
|---|---|---|---|---|
| Average growth | Natural growing colonies (whole colonies) | 25.875 ± 1.4058 | 23.533 ± 1.2018 | 49.408 ± 2.4105 |
| Range | | 20.15 - 30.05 | 21.04 - 28.36 | 41.71 - 58.41 |
| Average growth | Transplanted fragments | 23.483 ± 0.9171 | 23.083 ± 1.001 | 46.567 ± 1.9094 |
| Range | | 19.2 - 29.7 | 18.5 - 29.3 | 38.2 - 59 |

**Figure 6.** The general anatomy of the autozooid (a), sclerite (b) and partofcolonysurface (c). {An. S: Anthocodial Stem; Ecto: Ectoderm; End: Endoderm; Go: Gonads; Mg: Mesogloea; Ms.F: Mesenteric Filament; O. D: Oral Disc; Ph: Pharynx; S: Siphonoglyph; Siph: Siphonozooid; Te: Tentacle.}.

**Table 2.** One-way ANOVA analysis of the coral fragments growth rate per 6 months.

|  | Sum of Squares | D.F. | Mean Square | F-Test | Sig. |
|---|---|---|---|---|---|
| Between Groups | 110.240 | 10 | 11.024 | 14.11 | 0.205 |
| Within Groups | 0.781 | 1 | 0.781 |  |  |
| Total | 111.022 | 11 |  |  |  |

Sexes of *S. glaucum* couldn't be distinguished by external characteristics, but by the microscopic examining for the transverse sections of the monthly collected autozooids and the siphonozooids polyps of marked colonies. The examined colonies illustrated that, the male gonads (spermatogenesis) or the female gonads (oogenesis) were formed and found only in the autozooids; while the siphonozooids are sterile and not include neither male nor female gonads. *S. glaucum* is a dioecious species (unisex) where the investigated colonies were separated and containing either the male gonads only or the female gonads only. The gonads of both sexes develop in the autozooids on the four lateral and the two ventral mesenteries (mesenteries at the side of the siphonoglyph). Gonads start their development initially from the primordial generative cells in the mesentery then be covered by the mesogolea and gastroderm is of the mesenteries (**Figure 7**) to be clustered and increased in size forming either male gonads (in the male colony) or female gonads (in the female colony). Gonads were observed extending at the posterior third part of the polyp length at the sub-stomodaeal region of the autozooids near the polyp base. The gonads mostly were not observed in the anterior part of the polyp.

**The Oogenesis:**

The mature female gonads were found swelling containing the young ova and detected during the months October-November 2006 covered by a common layer of endodermal cells of the mesenteries. Different stages of the young ova that are still attaching to the mesenteries (mature gonads) in addition to little of the pre-mature ova were detected through the period from December to the following February 2007.

The ova were separated from the mesenteric filament forming the oocytes in October 2006 (**Figure 7(c)**). The free mature oocytes reached about 400 - 450 µm (**Figure 7(d)**) and were recorded in the coelenteron at the sub-stomodaeal region, then the mature oocytes were moved to the anterior part of the autozooid during December to the next January 2007 where it apparently becomes ready for fertilization (**Figure 8(a)**). The autozooids becomes empty in the end of February to May 2008 (**Figure 8(b)**), but the mesenteries simply started to be swollen in July perhaps for the new reproductive cycle which will repeated again. Investigation of the autozooids began in October 2006 and was continued to July 2008, where the maturation of the oocyte took in probability 20 -23 months.

**Spermatogenesis:**

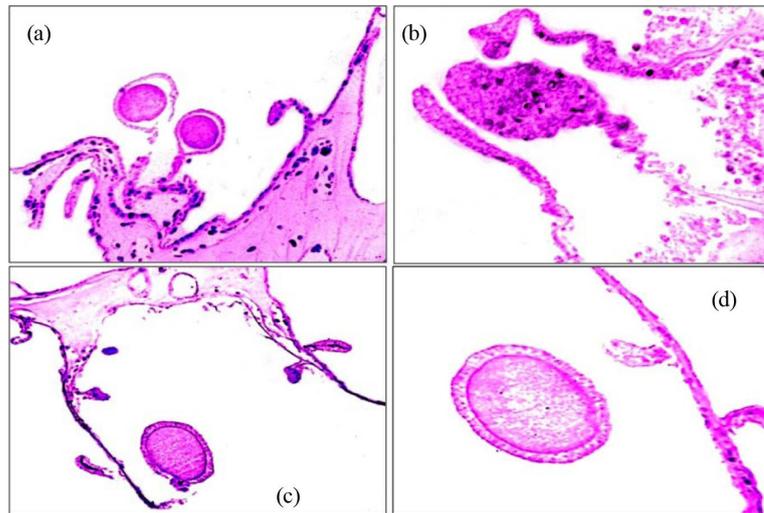The immature male gonads (spermatogonia) started slightly swelling into the mesenteries including the pri-

**Figure 7.** The ova at different maturity stages, some still attached to the mesentery by stalks (a); the mature female gonad extended posteriorin the autozooid ×400 (b); the pre-mature ova still attaching to the mesenteries at the sub-stomodaeum region (c); the detached mature ova in the coelenteron's cavity ×200 (d).



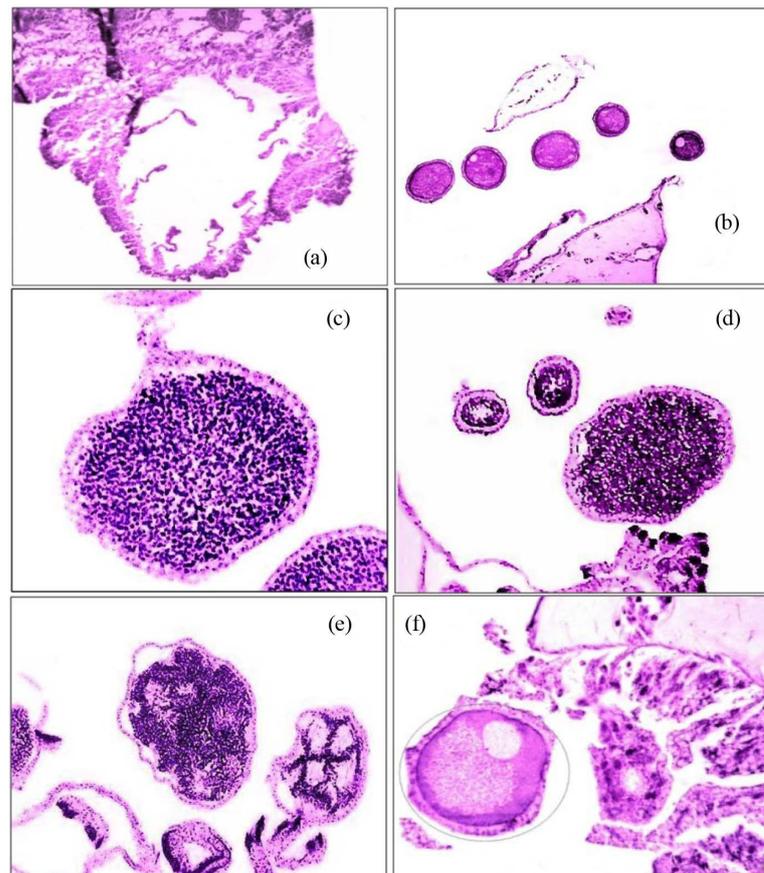**Figure 8.** Free mature oocytes at the sub-stomodaeum region ×100 (a); the simple swelling at the periphery of the mesenteries ×100 (b); spermary attaching to the mesenteries and completely filled with the spermatocytes ×400 (c); the different developmental stages of spermaries ×200 (d); the free spermaries in coelenteric cavity of autozooid (e); the planulae larvae incorporated within the autozooid ×200 (f).

mordial generative cells and are covered by both of the mesogloea and the endodermal layer of the mesenteries; they were detected at the sub-stomodaeal region during the February 2007. Spermatocytes were formed within spherical cysts (spermaries) from April to August 2007 filling up all cavities of the posterior portion of the autozooids of another colony. The young spermaries are attaching to the mesenteric filaments at the sub-stomodaeal region and are densely packed with the spermatocytes and including a central cavity with spherical and not flagellated cells (**Figure 8(c)** and **Figure 8(d)**).

Further development by successive division and increasing in number takes place then the spermatocytes developed into the spermatozoa, where the spherical cells became flagellated, the flagella are extending to the center of the spermaries. The spermary that including the pre-mature spermatozoa reached to 300 - 400 µm in size and a small cavity appeared in the center. Mature spermatozoa were completed their formation during the last days of November to December 2007, where the spermary ranged between 500 and 600 µm (**Figure 8(e)** and **Figure 8(f)**). It was difficult to detect the shedding process of the sperms. The build-up of the spermatogenesis generally takes less than 12 months.

### 3.3. Reproduction and Spawning Season

**Spawning Season & Planulae Larvae:**

*S. glaucum* is a brooder species, where, fertilization and development takes place internally; this fact was concluded when the planulae larvae shed in the laboratory aquarium in the last days of January 2008 (**Figure 9(a)** and **Figure 9(b)**), where, it was noticed that the autozooids expelled brown minute tissue. After the investigation, the authors found the water containing the larvae of the species, which are counted to reach to about 30 larvae approximately belonging to a piece of *S. glaucum* measured 30 cm$^2$. According to the timing of the shedding of the planulae larvae that occurred in the last days of January and beginning of February 2008, so we can concluded that, fertilization took place at the end months of 2007, and it was observed that the female gonad develops before those of the male, where the female gonad begins its development in the last days of October 2006, while the male gonads begins its development in the last days of February 2007.

Number of the collected larvae reaches to about 30 larvae approximately belonging to about 40 autozooids only of a collected colony. The larvae are rounded ciliated forms, having negative buoyancy and observed to swim in a rotary manner containing very small tentacles (eight tentacles) at the oral disc surrounding it. These cilia are very fin help the larvae in swimming, which reached to about 300 micron. The posterior end of the larvae contains a disc-like structure which will form the colony substrate with its stalk.

## 4. Discussion

### 4.1. Growth Rate

*S. glaucum* could not constitute a fixed shape during the current study, this is may be due to its irregular shape and the rapid changes in its shape during touch or slight disturbance, in addition of its great sensitivity for losing water that cause shrinkage and death of the colony in some cases. *S. glaucum* is one of the most common and frequent alcyonarian soft coral species which were chosen to measure and determine their growth rate, using a modification of Bake [28] method which was used for measuring growth rate of hard corals. Bak [28] studied the growth of *Montastrea annularis* and *Madracis mirabilis* as hard coral using a new technique of buoyancy of colony weight. Mitchell [32] applied new method for measuring the growth rate of two gorgonians corals *Leptogorgia hebes* and *Leptogorgia virgulata* through the study of the annual periodicity, Marschal [33] used another new technique to determine the age of the red coral *Corallium rubrum* colonies based on staining the organic matrix found in the axial calcareous skeleton. Holbrook and Schmitt [34] studied the growth rate of the sea anemone *Heteractis magnica* and related it to the presence of the mutualist or absence. At the present study, the normal weighing technique was used for *S. glaucum* with a modification of Bak's method due to its irregular shape and the rapid changes in its shape during touch or slight disturbance, in addition of its great sensitivity for losing water that cause shrinkage and death of the colony. Generally, the growth rate of family alcyoniidae was avoided due to the difficulties in the growth determination and due to the softness of the coral animal, and most of the growth rate investigations are applied on the hard corals. High potential for asexual propagation, fast growth rates characterize the nephtheid *Dendronephthya hemprichi* from the red sea [35]. The late authors studied the growth rate of *Sinularia* and *Sarcophyton* on the mid- and the outer-shelf reefs of the Great Barrier Reef, using tagging colonies over 3.5 years.
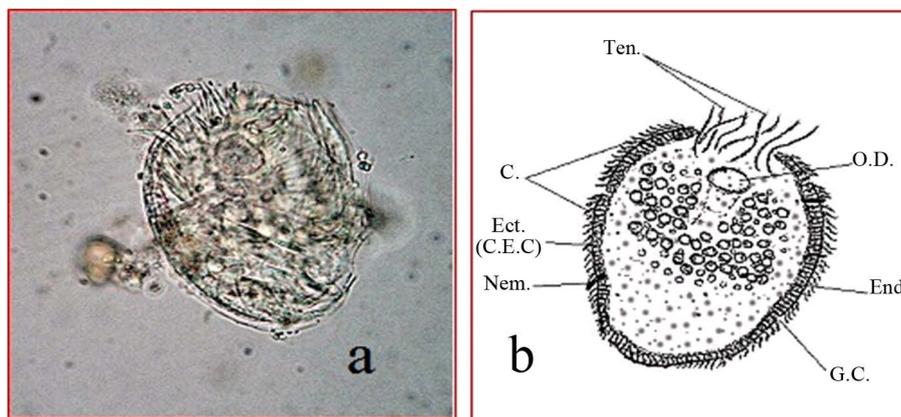
**Figure 9.** Planulae larvae of *Sarcophyton glaucum* (a); Photomicrograph of the planulae larvae ×200 (b). [C: Cilia; C.E.C: Columnar Epithelial Cells; Ect: Ectoderm; End: Endoderm; G.C: Glandular Cell; Nem: Nematocyst; O.D: Oral Disc; Ten: Tentacles].

Many physical and chemical factors affect the growth of the corals such as temperature, salinity, dissolved oxygen, sedimentation, turbidity and water motion [25] [36] [37] (Mc Cain *et al.*, 1984; Kotb, 1996; Mohammed, 2003). Additionally, Vine [38] reported that the sea water temperatures in shallow areas of the Red Sea were close to the optimum range for coral growth (25˚C - 29˚C). So, temperature is considering one of the most important factors that influence the growth rate of corals and their distribution, particularly in the Red Sea [39]. Where, the growth rate of *S. glaucum* during the present study is promoted and fast in summer (warm season), while it is almost crippled in winter. The growth may be detained in winter due to the devotion of a large part of metabolism to reproduction rather than to growth [12]. Where, the animal exploits its energy in the formation of gonads. The most of the year is being exploited especially the winter and the autumn seasons and little of the summer season for the formation of the gametes stages [40]. While during summer seasons, the highest growth rate may be referred to the end of gonad formation and be ready to release gametes, where, the average growth in the present study is ranged between $23.48 \pm 0.92$ gm/6 months (Spring & Summer) and $23.08 \pm 1$ gm/6 months (Autumn & Winter) for the fragmented colonies; while the average growth rate of the naturally grown colonies are higher than the fragmented ones and recorded $25.875 \pm 1.4058$ gm/6 m in summer and $23.533 \pm 1.2018$ gm/6 months in winter with an annual average growth reached $49.408 \pm 2.4105$ gm/y and $46.57 \pm 1.9094$ gm/y for the naturally grown and the fragmented colonies respectively [40].

The growth rate of *S. glaucum* is considered higher than some other soft corals which previously studied by Putri and Fahrudin [15] who found that, *S. glaucum* grow faster than *Nepthia* sp. with as survival rate of 100%. According to Harriot and Fisk [41], coral transplantation declared successful if survival rate of transplanted coral fragments reaches more than 50%. Moreover, according to Rocha [22], the present study illustrated that, there is no significant difference in the growth rate of the transplanted fragments with survival approximately 100% [13] [15].

Benayahu [42] mentioned that, *Sarcophyton glaucum* increased a few millimeters per year in colony diameter from the northern Red Sea. He illustrated that, the nutrients affect the growth rate of alcyoniids and has a broad physiological tolerance. During the present study there, no effects for the nutrients on the growth rate of *S. glaucum* (may be in their optimal or normal range). Cornish [43] reported that, colonies of large sizes grew with higher rates than the small sizes for the alcyoniid corals. The present study illustrated that, the colonies of medium sizes appeared to grow faster than the smaller ones where the average annual growth rates of the natural growing colonies recorded a relatively higher rate ($49.408 \pm 2.4105$ gm/y) than the fragmented colonies ($46.567 \pm 1.9094$ gm/y).

## 4.2. The Sexual Reproduction of *S. glaucum*

Three different forms of sexual reproduction are common in the soft corals; broadcasting of eggs and sperm, internal brooding of larvae, and external brooding of larvae; where, the internal brooding occurs when a small number of eggs has fertilized and develop into larvae inside the females. Days to weeks later, the larvae are re-

leased when they are almost ready for metamorphosis [44]. The frequency of brooding versus broadcasting spawning in Octocoral varies with taxonomic order. Brooding is common in the Order alcyonacea [45]-[47]. *Sarcophyton glaucum* is a member of the order alcyonacea. On the other hand, Coll [48] consider broadcast spawning to be the most common sexual reproductive strategy for alcyonacean.

Benayahu and Schleyer [49] examined the species of *Anthelia glauca* and reported that the months January to March is the peak of the breeding season, the brood of species is found within the pharyngeal cavity. Slattery [40] described the mass spawning behavior of the soft coral *Sinularia polydactyla*; the gametogenic cycle of female colonies lasted 12 months while male colonies produced viable sperm within 9 months, and the species exhibited a split spawn between March and June. Moreover, the reproductive cycle of a female *S. polydactyla* colony requires one year for the production of mature eggs. In contrast, spermatogenesis within male colonies of *S. polydactyla* lasted less than one year. Gohar [4] stated that the gonads of the *Xeniidae* are developing on the six ventral and lateral mesenteries but not the dorsal pair. The author elucidated that the hermaphroditism is defining in *Heteroxeniafuscescens*, *H. ghardaqensis* and *H. elizabethae*, but not in *H. capensis*, also all other species of *Xenia*, *Anthelia* and *Sympodium* were found to be unisexual. All the species of the genera *Xenia* and *Heteroxenia* in the Red Sea, with the exception of *Xenia garciae*, are brooding species. Benayahu [50] described the reproductive patterns and developmental pathway of 21 xeniid species in the Red Sea. Gonochorism is the commonest sexual mode but simultaneous hermaphroditism was recorded in four species and brooding of planulae was observed in 15 species. Dahan and Benayahu [51] studied the sexual reproduction in the a zooxanthellateoctocoral *Dendronephthya hemprichi* and stated that the sperm and egg release were observed in the laboratory at night on all dates, from October 1989 to April 1991; the soft coral *Dendronephthya hemprichi* is a gonochoric broadcast spawner, reproducing all year round. Sexual reproduction of the Alcyonacean octocoral *Lobophytum pauciflorum* should be stated that was studied by Fan [52] through histological examinations of gonad development on monthly samples. *Lobophytum pauciflorum* is a gonochoric broadcast spawner; mature eggs were 400 - 870 µm in diameter. Oogenesis and spermatogenesis took about 12 months. Spawning occurred from July-September during late summer to early autumn.

The present work elucidated that *S. glaucum* is a brooder species, where fertilization takes place internally during December 2006/January 2007. It was observed that the female gonad develops before those of the male, where the female gonad began its development in the last days of October 2006, while the male gonads began its development in the last days of February 2007 up to December. However, the oogenesis exhibited prolonged about 23 months, which gave rise to oocytes of different developmental stages in female colonies at any given time, and a spermatogenic cycle of only 10 - 12 months. These features are shared with *S. elegans* on the GBR [53] who pointed out that, the oogenesis took 19 - 24 months, with a new cycle commencing every year, and spermatogenesis took 10 - 12 months as well as *Lobophyton crassum* in Okinawa [5], and *Sinularia polydactyla* in Guam [40].

The present study reported and revealed that the mature oocyte of *S. glaucum* with a diameter of 400 - 450 µm was recorded in December 2006, and the oocyte growth proceeded in probability through about 20 - 23 months. In contrast, Benayahu and Loya [10] stated that the mature oocyte with a diameter of 500 - 650 µm was recorded in July, and the oocyte growth proceeded through 22 - 23 months, while Schleyer [54] stated that the gametogenesis in male and female colonies of *S. glaucum* takes 9 - 10 and 16 - 18 months respectively and spawning occurs annually in March. Additionally, the present investigation reported that the reproductive cycle the male *S. glaucum* colony attained the maturity and the free mature spermaries with a diameter of 500 - 600 µm have been appeared in December 2006 and their build-up takes less than 12 months, while Benayahu and Loya [10] reported that the young spermaries are found during August-September and their build up generally takes 10 - 12 months and approximately reach to 400 µm prior to spawning (**Table 3**).

The reproductive cycle of *S. glaucum* for production of the mature eggs is characterizing to be prolonged, there is an agreement to what was stated that brooders of all taxa soft corals or others typically have prolonged reproductive periods (gametogenesis and planula release) [55], this may confident our result about the manner of *S. glaucum*, where during the present study, it is noticed that the development of their eggs occurred internally inside the female polyps to be fertilized and developed into larvae; whereas, the larvae were collected at the laboratory aquarium from the autozooids of the female colonies, where, some coral species releases planula larvae after internal fertilization or release gametes, during colonies transportation to the laboratory [56], therefore, the colony transportation may be considered as a stressful condition that cause the coral respond to release of their sexual products [57]. On the other hand, Benayahu and Loya [10] at the Northern Gulf of Eilat and Schleyer *et al.*

**Table 3.** A comparison between the present study and the other studies in gonads development of *Sarcophyton glaucum* and other species.

|  | Oogenesis | Spermatogenesis | Mature oocyte | References |
|---|---|---|---|---|
| *S. glaucum* | In probability 20 - 23 months | <12 months | December-January | Present Study (2008) |
| *S. glaucum* | 22 - 23 months | 10 - 12 months | July | Benayahu & Loya (1986) |
| *S. glaucum* | 16 - 18 months | 9 - 10 months | March | Schleyer *et al.* (2004) |
| *Sinularia polydactyla* | 12 months | 9 months | March-June | Slattery *et al.* (1999) |
| *Lobophytum pauciflorum* | 12 months | 12 months | July-September | Fan *et al.* (2005) |

[54] in KwaZulu-Natal, South Africa indicated that, the soft coral *Sarcophyton glaucum* is a broadcasting species with externally developing larvae; where they pointed out that, the gametes were externally fertilized forming larvae. The present study pointed out that, there is a conflict between the present work and their results in the point of the formation of the larvae; where, the fertilization occurred internally producing the mobile ciliated larval stage. These results may illustrates the reproductive manner of the soft coral *S. glaucum*, but the difference may be due to some environmental factors which could affect their physiological responses as in most of the marine invertebrates, specifically gametogenesis formation, via coordination of intrinsic hormonal signals [58]. Moreover, the temperature is an important factor may affect the reproduction as well as the growth and coral distribution. On the other hand, the geographic distribution of reef corals and other coral reef organisms may control the timing of reproduction and reproductive behavior, as well as the seasonal changes in the abiotic features that may affect the reproduction manner; it was clearly mentioned that the seasonal changes of the water may have an impact on reproduction in *Heteroxenia fuscescens* [59].

In both sexes, gonads develop along the ventral and lateral mesenteries, often in the basal region of the polyp [60] [61]. The transverse sections of the autozooids and the siphonozooids polyps of the examined colonies were investigated to record and reveal that either the autozooids not the siphonozooids are including the stages of the oogenesis or the female sexual component (oocytes) mostly in the coelenteron (at the sub-stomodaeal region) of the most collected autozooids. Additionally, the autozooids are including the stages of the spermatogenesis or the male sexual component (spermaries) in the coelenteron (at the sub-stomodaeal region) of few collected mature autozooids that were collected from the middle of the colony disc. The siphonozooids of the examined colonies are sterile not include neither male nor female components. *S. glaucum* according to the later outcome is a dioecious species its colonies are separated into male and female colonies [10] [54]. The oogonia or primary oocytes first appear within the mesogloea of the septa [62] [63]. The common observation is that Scleractinian gametes develop within the mesogleal linings (lamellae) of the septa (mesenteries) which partition the coelenteron [57]. Germ cells originate in the gastrodermis and are initially surrounded by a layer of mesogloea with overlying gastrodermis [64]-[66]. Clusters of primordial germs cells are often attached to mesenteries (or mesentarial filaments in *Pennatulacean*) by a short pedicel of "stalk" [60] [67] [68]. The present study assures the entire previous conclusion, where the primary reproductive female components and the primary reproductive male components have been recorded attaching to the periphery of the mesenteric filament.

Hwang and Song [69] elucidated that the planulae of the soft coral *Dendronephthya gigantea* is ciliated planulae that had negative buoyancy after planulation, and showed rapid metamorphosis into a primary polyp stage within 2 days. Ben-David-Zaslow [59] recorded that the planulae of the Alcyonarian soft coral *Heteroxenia fuscescens* released during summer and is longer, with almost zero percent deformation. Fully formed Scleractinian larvae are elongate flagellated forms with ectoderm, mesoglea, and endoderm surrounding a central coelenteron [57]. Swimming planulae of Scleractinian have common behavior patterns Most planulae are observed to swim in a rotary clockwise and counter-clock-wise manner around the anterior-posterior (aboral-oral) axis [70]. During the present study, the recorded planulae larvae are moderately agreed to what was stated by Fadlallah [57] and Hwang and Song [69], but is conflicted with Ben-David-Zaslow [59], where, our observed larvae are rounded ciliated forms, having negative buoyancy and watched to swim in a rotary manner around the anterior-posterior containing very small tentacles (eight tentacles) at the oral disc surrounding it, and the cilia are very fin help in the larval swimming.

## 5. Conclusions

It was concluded that:

- Temperature fluctuation between summer and winter influences the growth rate, so growth is faster in summer and slower in winter.
- High sedimentation rates and water currents are some factors affecting the growth rate especially in winter.
- Fragment size is the effective factor for fragments growth which causes the decrease of fragments growth than the naturally grown colonies.
- Reproduction is another factor affecting and reducing the growth in winter due to the devotion of a large part of metabolism to reproduction rather than to growth.
- Autozooid polyps of *S. glaucum* are the reproductive organs while siphonozooids are sterile.
- The oogenesis exhibited prolonged about 23 months, which gave rise to oocytes of different developmental stages in female colonies at any given time, and a spermatogenic cycle of only 10 - 12 months.
- Fertilization occurs internally and form larvae which librated at late February to liberate planulae larvae librated during February.

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