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Reproductive pattern of *Pterocliadiella capillacea* (Gelidiales, Rhodophyta) at Canary Islands (Spain, Atlantic Ocean)

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ABSTRACT

Objective: To record the reproductive pattern of a natural population of *Pterocliadiella capillacea* from Gáldar (Canary Islands, Spain) from February to August in relation to temperature, irradiance and photoperiod environmental conditions.

Methods: Field observation of reproductive thalli was used at different seasons in the year.

Results: Tetrasporophytes and vegetative thalli were observed during all the period of study, while female gametophytes bearing cystocarps have been found from May to August in correspondence with the highest water temperature and irradiance values.

Conclusions: Our data suggest that the temperature may be the determining factor which regulates the presence of tetrasporophytes in the field. The constant presence of tetrasporophytes could depend on the low excursion range of water temperature (4–5 °C) throughout the period of study, with the highest abundance in February at 20 °C.

1. Introduction

Pterocliadiella capillacea (S. G. Gmelin) Santelices & Hommersand (Gelidiales, Rhodophyta) (*P. capillacea*) is a red algae with a worldwide distribution in temperate and tropical waters^[1–9]. On the North Atlantic coast, it occurs at both the intertidal and subtidal level and it is especially restricted to rocky areas with strong water motion^[10,11].

This species is characterized by a *Polysiphonia*-type life cycle^[12], with isomorphic phases: haploid dioecious gametophytes alternate to diploid tetrasporophytes and as a result of oogamic fertilization, a diploid carposporophyte developing on the female gametophyte. Little is known about factors affecting the reproduction occurrence of this cosmopolitan alga and studies about the influence of environmental factors on its reproduction may help to understand conditions regulating the alternation of haploid and diploid phases. Data have been reported from other biogeographical regions such as Brasil^[13], Mexico^[14], Italy^[15], and some studies have been done on

other Gelidiaceae in Canary Islands^[16,17], but no data are available on the reproductive pattern of *P. capillacea* from Gran Canaria (Canary Islands).

The peculiar environmental conditions of the Canary Archipelago, due to the combination of its geographical position, paleoclimatic events and oceanographic conditions, allow the presence of a high level of endemics^[18] and at the same time could affect the main morphological characters and reproductive pattern of species widely distributed as *P. capillacea*. The aim of the present work was to assess the reproductive pattern of *P. capillacea* in relation to environmental conditions characteristic of the island, such as water temperature, photoperiod, and global radiation.

2. Materials and methods

2.1. Study site

Canary Islands (Figure 1) have volcanic origin and their rocky coastline consists mostly of weathered basalt, bathed by the relatively cold water of the Canary current flowing from North–North–East; salinity in oceanic waters around Canary Islands is stable at 37‰. The number of raining days of at least 0.1 mm precipitation is minimal at Gran Canaria (maximum 6 d during December 2004)^[19].

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Figure 1. Map indicating the study site at Bocabarranco, Gáldar (Canary Islands, Atlantic Ocean).

Fertile and vegetative thalli of *P. capillacea* were collected at Bocabarranco, Gáldar (28°10′52″ N, 15°39′57″ W, Gran Canaria, Canary Islands, Figure 1). At this locality, a natural population of *P. capillacea* was collectable at the intertidal only during low tides on a wide slightly sloping rocky platform, where it formed a well defined band. In fact, at Bocabarranco, it has been possible to observe different belts in vertical zonation according to the tidal level: at the upper intertidal we found a belt characterized by the prevalence of *Enteromorpha* sp., at the intertidal a belt characterized by *Laurencia* sp. and *P. capillacea* followed by a belt of *Gelidium arbuscula* and a lower belt of *Gelidium canariense* which extended at the subtidal. The *Laurencia* sp.–*P. capillacea* community experienced emersion only for 1–2 h during low tide and the exposure to high light intensity produced bleaching of the thalli on these species. The high hydrodynamics and the beaten waves on the coast make impossible to reach Gelidiaceae during high tide (e.g. by diving) or when bad weather conditions (strong winds and currents) affect the zone.

Figure 2 shows mean sea surface temperature (MSST) and photoperiod of this locality during the sampling period, while mean global radiation (MGR) is represented in Figure 3.

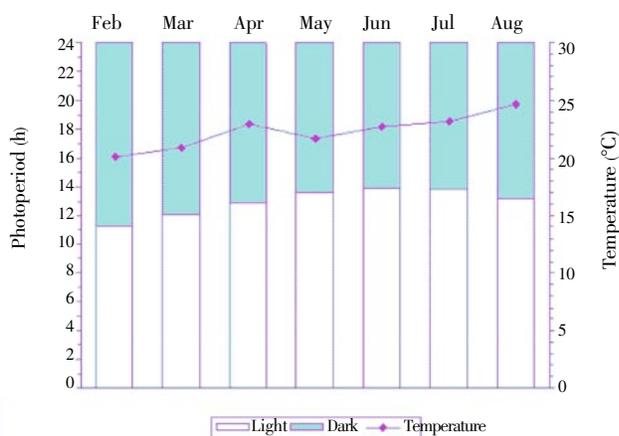


Figure 2. Photoperiod and MSST from February to August 2004 at Bocabarranco, Gáldar (Canary Islands, Spain).

Since buoys measurements weren't representative of coastal waters and ground measured solar radiation datasets weren't available for this given site, we used satellite-based data and specific correction algorithms. For sea surface temperature (SST) we used AVHRR Pathfinder Version 5.2 (PFV52) data, obtained from the US National Oceanographic Data Center and GHRSSST (<http://pathfinder.nodc.noaa.gov>, Arbelo et al.[20]). MGR data have been obtained from the NASA Langley Research Center and Atmospheric Science

Data Center. Surface meteorological and Solar Energy (SSE) web portal supported by the NASA LaRC POWER Project (SSE Release 6.0, <http://eosweb.larc.nasa.gov>, Kilpatrick et al.[21]).

Despite MSST and MGR are satellite-derived variables, nowadays geostationary satellites provide the opportunity to derive information on solar irradiance and SST for large areas at a good temporal and spatial resolution. Derived hourly values have proven to be at least as good as the measurements of a ground station at a distance of 25 km (Zelenka et al.[22]). Furthermore, independent algorithms allow daily data validation and, in the case of SST, the matchup with *in situ* buoys datasets.

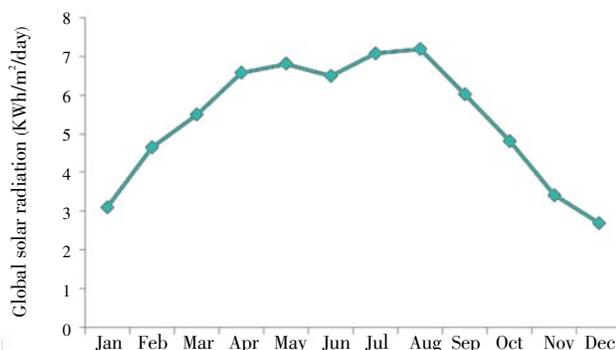


Figure 3. Mean global solar radiation at Gran Canaria (Canary Islands, Spain).

2.2. Sampling

Sampling was carried out from February to August 2004. Bad weather conditions precluded sampling in April and in autumn. The alga was collected by hand, taking care to collect the whole thalli. Considering the structure of populations and the pattern of aggregation of thalli, 20 clumps were collected each month from aggregations which were at least 20 cm apart, in order to avoid sampling the same individual. The collected samples were immediately placed in separated plastic bags, maintained cold inside an ice cooler and transported to the laboratory of the Departamento de Biología at the Universidad de Las Palmas de Gran Canaria as soon as possible. The time elapsed between the collection of the algae and their treatment was no longer than 4 h. Thalli were examined under a Wild M3Z Heerbrugg dissecting microscope and under an Olympus CX41 microscope, and identified following Santelices and Hommersand[5]. Part of the algal material from each population was desiccated on herbarium sheets and pressed; part was preserved in 4% formalin/seawater solution. A herbarium sheet was catalogued in the BCM Herbarium (Departamento de Biología, Universidad de Las Palmas de Gran Canaria–BCM 6618) for further observations. Clumps were sorted into reproductive and vegetative ones according to the presence/absence of reproductive structure respectively. Female upright axes were recognized by the presence of cystocarps and tetrasporophytes by the presence of tetrasporangia, considering as well the presence of empty reproductive structure in the recognition of the phase.

3. Results

Environmental conditions observed at Bocabarranco were

characterized by a high water motion, a temperature ranging from 20 °C to 24.6 °C, light/dark regime varying from 11 L: 13 D in February to 14 L: 10 D in June and July (Figure 2), the tidal amplitude ranging from a mean high tide of (2.26 ±0.27) m to a mean low tide of (0.70±0.26) m. Clumps were reddish–brown to purple in colour that in some cases appeared as bleached. Erect axes directed upwards and were oppositely or alternate distichously branched three to five times. Secondary branches usually started at half of the main axis. Prostrate system consisted of creeping axes.

We found only one reproductive phase and vegetative thalli within the same clump. Tetrasporic clumps were predominant over other phases of the life cycle (Figure 4) and they were present during all the studied period with the highest abundance in February (84.74%) and the lowest in August (50%). Female fertilized gametophytes have been observed mostly in August, with an increasing occurrence from March (0.36%) to August (9.84%). No male gametophytes were observed during the period of the year considered in this study. Vegetative thalli were most abundant in June (42.60%) and reduced in February (15.26%). The relative proportion between tetrasporophytes and fertile gametophytes in the population from Bocabarranco in the studied period was of 14:1 (t:g), calculated on the basis of the total amount of tetrasporophytic and gametophytic clumps recorded during the study.

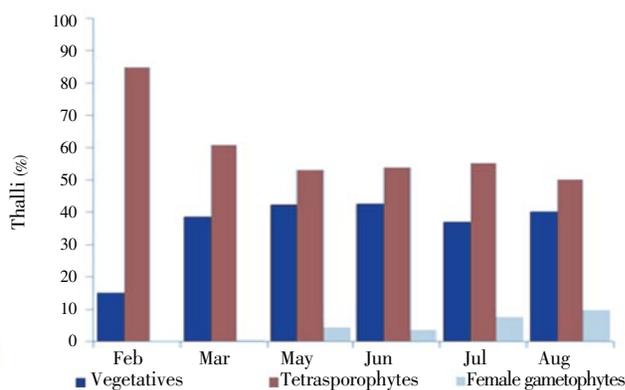


Figure 4. Reproductive and vegetative phases of *P. capillacea* at Bocabarranco (Gáldar, Canary Islands) from February to August 2004.

The increase of female fertilized gametophytes seems to be related to the increasing temperature, higher than 23 °C. On the opposite, tetrasporic clumps were most abundant at the lowest temperature and their percentage was almost constant during the hot season, reaching the lowest percentage in August (40% at 24.6 °C).

4. Discussion

High light intensity, temperature and desiccation stress at low tide could be the cause of the loss of pigments and bleaching observed in the thalli of both *P. capillacea* and *Laurencia* sp. at Bocabarranco (Gáldar). In fact, Martone *et al.* indicated the exposure to high light intensity as the main factor responsible for bleaching in thalli of coralline algae[23], and Häder *et al.* found a high photoinhibition in *Gelidium arbuscula* and other Rhodophyta after direct exposure to unfiltered solar radiation[24].

In most of the studies on the reproductive phenology of *P. capillacea*, gametophytes were reported as rare or with frequencies limited to a defined period of the year or with low abundance. Oliveira and Sazima found in Brazil male thalli from December to April and female only in April[25]. Dixon and Irvine found tetrasporophytic and gametophytic thalli only in June and October[26]. Oliveira and Berchez for *P. capillacea* in Brazil found sexual plants in low frequencies (3%–4% of female gametophytes) throughout the year[13]. Neto found only one cystocarpic bearing gametophyte in April at Azores[8]. In Mexico, Servière–Zaragoza and Scrosati found male and female gametophytes only in January with abundance of 0.10% and 0.15% respectively[14]. Bottalico *et al.* reported in the Adriatic Sea (Italy) female gametophytes bearing cystocarps only in August[15]. Polifrone *et al.* found female and male gametophytes in populations of Tenerife during summer and autumn respectively[17]. At Bocabarranco, female gametophytes were present from March to August, increasing during these months in accordance with the increase of temperature and MGR. Due to such high variability at different latitudes, it could be possible that other factors independent of the temperature, irradiance and latitude could influence their development and survival in natural populations[27].

We could find neither male gametophytes nor thalli that had by that time released male gametes and left empty structures. Bottalico *et al.*[15] in the Adriatic Sea and Neto[8] in Azores did not collect any spermatogonial ramets of *P. capillacea* throughout the year, but in our case the lack of male gametophytes could be due to other factors. Since the female gametophytes were distinguished on the basis of the presence of the cystocarp on gametophytic thalli, it could be possible that the male gametophytes developed during the autumn period, before of our observations, or that part of the vegetative clumps recorded were undifferentiated male gametophytes.

The prevalence of tetrasporophytes over gametophytes found at Bocabarranco was also observed by other authors[8,13–15,17], although the proportion of tetrasporophytes at the studied population was lower than the described elsewhere. In fact, in *P. capillacea* of Brazil, Oliveira and Berchez observed a ratio of 50% of tetrasporophytes against 1%–2% of male gametophytes and 3%–4% of female gametophytes[13], and Polifrone *et al.* reported a sex ratio of 1:1:133 (m:f:t) for *P. capillacea* from Tenerife (Canary Islands)[17]. At different latitudes, the presence of tetrasporophytes was not constant and it could be observed the same pattern about the response to the temperature. Bottalico *et al.* observed the presence of tetrasporic upright axes in two populations of the Adriatic Sea (Italy) from June to September with the highest abundance (80%–83%) in July at a temperature of 20 °C[15]; Neto[8] found them only in summer–autumn at Saõ Miguel (Azores), while Serviere–Zaragoza and Scrosati reported their occurrence throughout the year with higher abundance in July at a temperature of about 18 °C[14]. At Canary Islands, the constant existence of tetrasporophytes in the studied period can be attributed to the slight variation of temperature throughout the year (*e.g.* from February to August the temperature range is between 4–5 °C) because of the influence of the Canary current

flowing southward, the North–North–East trade winds and the presence of several cyclonic and anticyclonic eddies which confer to the archipelago colder water temperature than the expected for its latitude^[28]. In Tenerife, Polifrone *et al.* found a higher percentage of tetrasporophytes during the summer–autumn^[17], though at temperatures of 21–24 °C and the highest percentage of tetrasporophytes at Gran Canaria (84.74%) was found in February at a temperature of 20 °C.

The decrease in tetrasporic clumps percentage corresponded to an increase of the vegetative ones, which could represent individuals of undetermined phase belonging to senescent thalli and/or to young thalli not yet differentiated. In this period of the year a possible demographic renovation of the population could occur, although another kind of study is necessary to validate this hypothesis.

Although further studies carried out over a larger period of time are needed to confirm the data obtained here, the present study gives a first insight on the reproductive pattern of *P. capillacea* at Gran Canaria and on the influence of temperature and irradiance on the occurrence of reproductive phases in the field.

Conflict of interest statement

We declare that we have no conflict of interest.

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