Ecological, Anatomical and Morphological Studies on
Ulva rigida C. Agardh (Ulvaceae, Chlorophyta) in the Coast of İzmir ( Aegean Sea-Turkey)

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Abstract: A series of morphological, anatomical and ecological characters of Ulva rigida collected from six locations along the coast of İzmir were determined. The size and morphology of thallus, thickness of marginal, mid and basal regions showed variations according to the changes in season and location. Ulva rigida consisted of smaller thalli in nutrient limited rough water coast and produced larger, lobed thalli which was characteristic of spring summer growth in relatively stagnant coast rich in nutrients. Thallus length and thallus breadth varied between 2-360 cm and 3-160 cm, respectively. The increased concentrations of nutrients due to the pollution were effective on anatomic and morphometric characters.

Key Words : Ulva rigida, green alga, eutrophication, morphology, anatomy

İzmir Kıyılarında (Ege Denizi-Türkiye) Ulva rigida C. Agardh
(Ulvaceae, Chlorophyta) Üzerine Ekolojik, Anatomik ve Morfolojik Çalışmalar


Anahtar Kelimeler : Ulva rigida, yeşil alga, ötrofikasyon, morfoloji, anatomi

Introduction

Recently, the Aegean Sea has been exposed to coastal eutrophication (Dural et al., 1989). Especially, İzmir bay has been heavily polluted by municipal and industrial wastes. Ulva rigida C. Ag. forms excessive populations in areas which has a low diversity due to the eutrophication. Ulva rigida has been found widespread along the shores of the Mediterranean (Malaa and Haritondis, 2000). Extensive blooms of Ulva rigida leading to anoxia in large parts of the Venice lagoon are rapidly reducing the quality of the ecosystem and affecting its use as a natural source for fishing, aquaculture and recreation (Runcu et al., 1996). Ulva rigida blooms resulting from pollution were also reported at the north-western Mediterranean (Rodriguez-Prieto and Polo 1999). It was reported that the chlorophyte Ulva lactuca was the most abundant organism in the intermediately polluted areas at Quequen, Argentina (Lopez-Gappa et al. 1990). The Brittany coast line where the slope of shore is gentle and the sand is fine, is consistently affected by annual Ulva sp. blooms (Piriou 1996). The similar shore structure together with high nitrogen flows especially in spring may enhance eutrophication in the coast of İzmir.

Ulvalies species were grouped into pollution tolerated algae (Boudouresque 1984) and there is a large scale distribution in İzmir bay and the outside of the bay. Eight species of Ulva were recognised in the coast of Turkey and Ulva rigida was the most common component. This species was frequently found in the inner bay after


Earlier studies based on the morphology, biology and culture of Ulva genus were done by Dangeard (1960,1963). Then, Bliding (1968) by undertaking a major revision of the genus, used a comprehensive list of anatomical and morphological characters to describe the eight species of Ulva from Europe. Later studies have been based on Bliding's work (Vinogradova 1974, Longo and Giaccone 1974, Hoeksema and Van Den Hoek 1983, Koeran 1985).
Bilding (1968) considered that pyrenoid number, thallus thickness, and size and arrangement of cells were non-variable characters. Subsequent studies focused on the variability of vegetative characters and have demonstrated that, in some Ulva species, thallus thickness, cell size and pyrenoid number are too variable for taxonomic use (Vinogradova 1974; Saifullah and Nizamuddin 1977). The changes in nutrient concentrations resulted from pollution may affect the morphological and anatomical characters in Ulva species. As a result, culture is necessary for taxonomical studies. But the cell shape in transverse section of the basal region were reported as non-variable characters in the southern Australian Ulva species (Phillips 1988).

This study involves a combination of extensive field and anatomical studies. Ulva rigida from different localities in the Izmir coast has been sampled in an attempt to evaluate the variation in morphological and anatomical characters due to the pollution.

Material and Methods

Izmir bay locates between 38°10'N, 38°40'N and 26°15'E, 27°10'E coordinates (Fig. 1). The bay is heavily polluted from industrial and domestic sources which decreases in the outer bay gradually. The deepest point is 15 m in the inner bay to the Narlıdere coast and there is no algae except some Cyanophyceae species. The middle bay (max. depth 45 m) locates between Narlıdere and Urla. Because the coast between Narlıdere and Urla shows high diversity, it is evaluated as moderately polluted area and the characteristic pollution tolerated algae are abundant. Urla, Balıklıova and Karaburun are situated in the outer bay. The pollution decreases from Urla to Karaburun gradually. Çeşme and Seferihisar are the least affected coast from pollution since they are located in the outside of the bay.

The samples were taken in January, April, August and November 1998. The samples of Ulva rigida were collected from the areas surrounding the point pollution sources in the six locations (Narlıdere, Urla, Balıklıova, Karaburun, Çeşme, Seferihisar) on gently sloping rocks and shells.

The concentrations of nitrite, nitrate, ammonia-nitrogen and orthophosphate were analysed in the water samples taken from the sampling locations according to Strickland and Parsons (1972). Temperature and pH were measured in situ. Attached individuals from the centre of distribution of the populations were collected. The following measurements were recorded: thallus length and breadth, and the thickness of the marginal, mid and basal regions of the thallus. The basal region of the thallus is defined as the non-rhizoid-containing region immediately adjacent to where there are rhizoids between the two cell layers. A subsample of 10 plants was selected and the following was recorded for each of 10 cells from the marginal, mid and basal region of the thallus: cell length and breadth (in surface view) and cell height (in transverse section) (Phillips 1988). Statistical analyses were performed by using Minitab and Mstat programmes for Windows. Variance analysis (ANOVA) and Duncan multiple range test were computed to evaluate the differences in terms of the parameters.

Result and Discussion

In Izmir coast, the morphology of Ulva rigida varied with the changes in location, season and developmental stages. Ulva rigida consisted of smaller thalli in nutrient limited rough water coast and produced larger, lobed thalli characteristics of spring summer growth in relatively stagnant coast rich in nutrients. Similar patterns of morphology has been reported for the European and southern Australian populations of Ulva rigida (Dangeard 1959, 1963, Phillips 1988). 90 % of total thallus from Narlıdere, 87.5 % from Balıklıova and 72.5 % from Çeşme, were found as orbicular, simple or lobed and slightly holed. 65 % from Urla, 60 % from Karaburun and 55 % from Seferihisar were lanceolate, margins towards the center were deeply lobed and fenestrated. These showed the effects of hydrodynamism on lanceolate structured individuals. The colour of plant was darker green in sheltered localities.

Ulva rigida populations showed a considerable variation in the size of thallus, cells and the thickness of thallus (Table 1). The variations in the thickness of marginal, mid, and basal regions; cell height in transverse section and cell size in surface section were found to be statistically significant by seasons and locations (p<0.05) (Table 2). Thickness of thallus was increased from...
Tablo 1. The mean (±Standard deviation), maximum and minimum values of morphometric parameters of U. rigida in 1998 (N=240)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean±SD</th>
<th>Max.</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL (cm)</td>
<td>26.4±2.58</td>
<td>360</td>
<td>2</td>
</tr>
<tr>
<td>TB (cm)</td>
<td>16.8±1.47</td>
<td>160</td>
<td>3</td>
</tr>
<tr>
<td>MT (µm)</td>
<td>52.4±5.40</td>
<td>75.9</td>
<td>34.5</td>
</tr>
<tr>
<td>MTC (µm)</td>
<td>18.8±0.22</td>
<td>27.6</td>
<td>11.5</td>
</tr>
<tr>
<td>MSCL (µm)</td>
<td>14.8±2.00</td>
<td>23</td>
<td>8</td>
</tr>
<tr>
<td>MSCB (µm)</td>
<td>12.4±1.17</td>
<td>20.7</td>
<td>5.3</td>
</tr>
<tr>
<td>MT (µm)</td>
<td>89.1±1.16</td>
<td>182</td>
<td>57.5</td>
</tr>
<tr>
<td>MTC (µm)</td>
<td>26.9±0.49</td>
<td>52.9</td>
<td>13.8</td>
</tr>
<tr>
<td>MISCL (µm)</td>
<td>15.6±2.23</td>
<td>28</td>
<td>9.2</td>
</tr>
<tr>
<td>MISCB (µm)</td>
<td>13.2±0.21</td>
<td>23</td>
<td>6.9</td>
</tr>
<tr>
<td>BT (µm)</td>
<td>140.5±2.33</td>
<td>255</td>
<td>64.4</td>
</tr>
<tr>
<td>BTC (µm)</td>
<td>33.7±0.52</td>
<td>57.5</td>
<td>11.5</td>
</tr>
<tr>
<td>BSCL (µm)</td>
<td>19.3±0.51</td>
<td>43.7</td>
<td>6.9</td>
</tr>
<tr>
<td>BSCB (µm)</td>
<td>16.1±0.41</td>
<td>44.1</td>
<td>6.9</td>
</tr>
</tbody>
</table>

*Abbreviations; TL; thallus length, TB; thallus breadth, MT; thickness of marginal region, MTC; cell height in marginal transverse section, MSCL; cell length in marginal surface view, MSCB; cell breadth in marginal surface view, MT; thickness of mid region, MTC; cell height in mid transverse section, MISCL; cell length in mid surface view, MISCB; cell breadth in mid surface view, BT; thickness of basal region, BTC; cell height in basal transverse section, BSCL; cell length in basal surface view, BSCB; cell breadth in basal surface view.

Marginal to basal region or from spring to winter. The different hydrodynamic factors like currents, wind, shape of shores were supposed to be effective on anatomical structure as morphology. Also, the increased concentrations of nutrients due to the pollution were effective on anatomical characters.

Tallus length (TL): The highest mean value of thallus length and the maximum value of U. rigida length were found in spring as 157 and 360 cm in Seferihisar, respectively. The values were decreased towards winter. The lowest mean value of thallus length and the minimum value were found as 4.4 and 2 cm in Urla in winter, respectively.

Tallus breadth (TB): The breadth of thallus was also larger in spring. The mean value of thallus breadth was 92 cm and maximum plant breadth was 160 cm in spring in Seferihisar. The lowest mean value of thallus breadth was 4.3 cm and the minimum value was 3 cm in autumn in Karaburun.

Thickness of the marginal region (MT): The highest mean value of marginal region thickness was 64.4 µm in autumn in Çeşme and Balıkgövde. The maximum value was measured as 75.9 µm in autumn in Çeşme. The lowest mean value was 40.7 µm in summer in Narlıdere and the minimum value was 21.3 µm in autumn in Karaburun.

Cell height in marginal transverse section (MTC): The highest mean value of cell height in marginal transverse section was 23.2 µm in winter in Balıkgövde. The maximum value was measured as 27.6 µm in autumn and winter in Balıkgövde too. The lowest mean value was 14.7 µm in spring in Narlıdere and the minimum value was 11.5 µm in spring and summer in Narlıdere, Urla, Karaburun and Seferihisar.

Cell length in marginal surface section (MSCL): The highest mean value of cell length in marginal surface section was 20 µm in summer in Çeşme. The maximum value was measured as 23 µm in spring and in autumn in Çeşme and Urla. The lowest mean value was 12.2 µm in spring and autumn in Balıkgövde and Karaburun and the minimum value was 8 µm in spring in Seferihisar.

Cell breadth in marginal surface section (MSCB): The highest mean value of cell breadth in marginal surface section was 16.8 µm in winter in Narlıdere. The maximum value was measured as 20.7 µm in summer in Çeşme. The lowest mean value was 9.7 µm and the minimum value was 5.3 µm in spring in Seferihisar.

Thickness of the mid region (MT): The highest mean value of mid region thickness and the maximum value were 128.3 µm and 185 µm in winter in Çeşme, respectively. The lowest mean value was 68.9 µm in spring in Urla and the minimum value was 57.5 µm in spring in Seferihisar.

Cell height in mid surface section (MTC): The highest mean value of cell height in mid surface section was 38.4 µm in winter in Balıkgövde. The maximum value was measured as 52.9 µm in winter in Karaburun. The lowest mean value was 17.7 µm in winter in Narlıdere and the minimum value was 13.8 µm in spring and summer in Narlıdere.

Cell length in mid surface section (MSCL): The highest mean value of cell length in mid surface section was 21.4 µm in spring in Narlıdere. The maximum value was measured as 26 µm in winter in Çeşme. The lowest mean value was 12 µm in spring and summer in Çeşme and Urla. The minimum value was 9.2 µm in spring, summer and autumn in Çeşme and Urla.

Cell breadth in mid surface section (MSCB): The highest mean value of cell breadth in mid surface section was 19.8 µm in spring in Narlıdere. The maximum value was measured as 23 µm in autumn in Narlıdere. The lowest mean value was 9.9 µm in summer in Urla and the minimum value was 8.9 µm in spring in Balıkgövde.

Thickness of the basal region (BT): The highest mean value of basal region thickness was 109.9 µm in winter in Çeşme. The maximum value was measured as 255 µm in winter in Çeşme. The lowest mean value was 89.5 µm in spring in Narlıdere and the minimum value was 64.4 µm in spring in Urla.

Cell height in basal transverse section (BT): The highest mean value of cell height in basal transverse section was 43.7 µm in winter in Balıkgövde. The maximum value was measured as 57.5 µm in autumn in Çeşme. The lowest mean value and the minimum value were 21.3 and 11.5 µm in spring and summer in Seferihisar, respectively.
Table 2. The changes in morphology and morphometric parameters of *U. rigida* in different locations and seasons (Means±SD) (*)

<table>
<thead>
<tr>
<th>Locality</th>
<th>Morpho</th>
<th>TL(cm)</th>
<th>TL(cm)</th>
<th>MTCM(pmm)</th>
<th>MTCM(pmm)</th>
<th>MSCM(pmm)</th>
<th>MSCP(pmm)</th>
<th>MTCM(pmm)</th>
<th>MSCP(pmm)</th>
<th>MTCM(pmm)</th>
<th>MSCP(pmm)</th>
<th>MTCM(pmm)</th>
<th>MSCP(pmm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narlıdere</td>
<td>Orbicular, simple</td>
<td>36.10±9.7</td>
<td>17.3±6.7</td>
<td>40.7±1.7</td>
<td>17.0±1.2</td>
<td>20.0±1.2</td>
<td>17.2±1.0</td>
<td>20.0±1.2</td>
<td>17.2±1.0</td>
<td>20.0±1.2</td>
<td>17.2±1.0</td>
<td>20.0±1.2</td>
<td>17.2±1.0</td>
</tr>
<tr>
<td>Urla</td>
<td>Orbicular, simple</td>
<td>3.64±1.6</td>
<td>4.44±2.3</td>
<td>4.04±2.3</td>
<td>4.04±2.3</td>
<td>4.04±2.3</td>
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<tr>
<td>Batılapı</td>
<td>Orbicular, simple</td>
<td>1.48±0.5</td>
<td>1.98±1.0</td>
<td>1.77±1.0</td>
<td>2.08±1.0</td>
<td>1.77±1.0</td>
<td>2.08±1.0</td>
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<td>2.08±1.0</td>
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<td>2.08±1.0</td>
</tr>
<tr>
<td>Karaburun</td>
<td>Orbicular, simple</td>
<td>1.14±0.3</td>
<td>1.48±0.5</td>
<td>1.50±0.5</td>
<td>1.98±0.5</td>
<td>1.50±0.5</td>
<td>1.98±0.5</td>
<td>1.50±0.5</td>
<td>1.98±0.5</td>
<td>1.50±0.5</td>
<td>1.98±0.5</td>
<td>1.50±0.5</td>
<td>1.98±0.5</td>
</tr>
<tr>
<td>Çeşme</td>
<td>Orbicular, simple</td>
<td>1.43±0.2</td>
<td>2.00±0.3</td>
<td>1.83±0.3</td>
<td>3.49±1.0</td>
<td>1.83±0.3</td>
<td>3.49±1.0</td>
<td>1.83±0.3</td>
<td>3.49±1.0</td>
<td>1.83±0.3</td>
<td>3.49±1.0</td>
<td>1.83±0.3</td>
<td>3.49±1.0</td>
</tr>
</tbody>
</table>

(*) Abbreviations are the same as Table 2.
Cell length in basal surface section (BSCL): The highest mean value of cell length in basal surface section was 36.1 μm in autumn in Narlıdere. The maximum value was measured as 43.7 μm in autumn in Narlıdere. The lowest mean value was 13.1 μm in summer in Seferihisar and the minimum value was 6.9 μm in summer in Urla.

Cell breadth in basal surface section (BSCB): The highest mean value of cell breadth in basal surface section was 31.3 μm in autumn in Narlıdere. The maximum value was measured as 41.4 μm in autumn and winter in Narlıdere. The lowest mean value was 10.8 μm in summer in Seferihisar and the minimum value was 6.9 μm in summer in Urla.

Thallus; simple-orbicular or lanceolate, often with 2-6 segments, or deeply divided into broad or linear lobes; often with many holes in the mid region, margins often membranaceous, entire or with small denticules. Thallus 35-76 μm thick in marginal region, 58-185 μm thick in mid region, 64-255 μm thick in basal region. The effects of ecological changes on the anatomical structure of Ulva were mostly determined in marginal section of thallus. The marginal transverse section did not change due to the disappearance of musilage in between. The difference resulted from the changes of the cell size. The thickness of marginal region was lower when the thallus length and breadth was higher in Narlıdere and Seferihisar. The maximum and minimum values of the thickness of marginal region were in agreement with Koeman (1985). It was reported as 38-42 μm by Bliding (1988), 40 μm by Hoeksema and Hoek (1983), 40-80 μm by Phillips (1984), 50-80 μm by Phillips (1988). The minimum value in our findings was lower than those of the reported values.

Cells in surface view, polygonal or quadrangular, 8-23 μm long and 7-23 μm broad in marginal region; 9-28 μm long and 7-23 μm broad in mid region and; 7-44 μm long and 7-41 μm broad in basal region. Cells in transverse section rounded, or rectangular; 12-28 μm high in marginal region, 14-53 μm high in mid region, 12-57.5 μm high in basal region. The cell height increased from marginal to basal regions. The similar pattern was also reported by Phillips (1988). The cell size in marginal region, as in surface view was reported as (11-18) X (7-11) μm by Koeman (1985), and (10-23) X (7-18) μm by Hoeksema and Hoek (1983). The palisade-like cells in the middle part were characteristic for the identification of U. rigida.

U. rigida was the most common species of Ulvales in the coast of İzmir as reported by several authors (Güner and Aysel 1978 Dural et al. 1989; Dural 1990). It grows on gently sloping sedimentary rock platforms and sandy beaches. It was reported that Ulva reaches a peak abundance during the early spring and plants may cover almost completely the rocky substratum and, the thallus length and breadth were 1.6-11.4 cm and 2.2-13.2 cm in the southern Australian populations of U. rigida (Phillips 1988). In this study, excessive growth of plants were observed and the max. length of plants reached to 360 cm around the point-pollution sources, such as waste pipes in

Fig. 2. The changes of nitrate, nitrite, ammonia and orthophosphate concentration by the seasons in the sampling locations (N; Narlıdere, U; Urla, B; Balıklıova, K; Karaburun, Ç; Çeşme, S; Seferihisar)
small bays. In the study period, mean values of water temperature were measured as 17.5°C for spring, 24.1°C for summer, 23.6°C for autumn and 14.3°C for winter. The values of dissolved oxygen varied between 13.4-2.4 mg/l and anoxic conditions were not determined. The seasonal variations of nitrate, nitrite, ammonia-nitrogen and orthophosphate concentrations in each of six locations were given in (Fig. 2). The concentration of nutrients varied with locations and seasons. Orthophosphate values were higher in Narlıdere and Çeşme in summer, ammonia-nitrogen was the highest in Çeşme in summer and spring, nitrite was higher in Narlıdere in spring and nitrate was the highest in Seferihisar in spring. The approximate temperature for the maximum growth rate of Ulva was reported as 20°C and nitrate is the limiting nutrient in sea (Duke et al., 1989). Phillips (1988), showed that rapid growth of thalli during early spring produces larger plants. The highest nitrate concentration resulted from a discharge of a restaurant was stimulate the growth and the highest mean values of thallus length and breadth were found in Seferihisar in spring. The thallus size of Ulva rigida in Seferihisar differed significantly from other locations in each season (p<0.05). The length of thalli reached to 360 cm where the nitrate concentration was 230.2 µg/l. In fact, this coast is clean and rich in oxygen. The length of thalli decreased towards to winter. After the rehabilitation of this discharge, none of Ulva species was found in this station.

The morphological and anatomical structure of Ulva rigida affected from the environmental changes. Some characters such as morphometric parameters were too variable for taxonomic use. But the identification of Ulva lactuca with anatomical and morphological characteristics which was reported in İzmir bay for many times was not easy as reported by Güner and Aysel (1977, 1978). The shape of the cells in mid region was characteristic for Ulva rigida. Because of being the easiest to identify in between Ulva species of Turkey, it might be used as an indicator of eutrophication or metal pollution in later studies.

References


