Morphological comparison of different *Caulerpa* J.V. Lamouroux species along Maharashtra and Gujarat coast, India.


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Species of *Caulerpa* form an important component of the algal group of intertidal ecosystem. Morphological variations among 8 species of *Caulerpa* collected from Gujarat and Maharashtra coast were studied. The genus showed marked differences in morphological characters between species collected from different sites. *C. taxifolia* collected from Malvan recorded highest height of 272 mm. Crowded assimilators were observed in *C. microphysa* (5.89/2 cm stolon). The protected environment such as tide pools is found to be more conducive as larger specimens were collected from these areas; here reduced wave action allowed species to grow relatively larger.

*Keywords: Caulerpa, Marine Macroalgae, Morphology Variation, Indian coast, Intertidal area.*

**Introduction**

Being a peninsular country, India has a long coastline (8129 km), with various kinds of habitats which support vast number of flora and fauna. There are around 844 species of seaweeds along Indian coast belonging to 217 genera.

Various species of green algal genus *Caulerpa* J. V. Lamouroux occur throughout the world, distributed from temperate to tropical marine waters. The genus consist of more than 85 species, all of which share the same basic morphological structure of thallus consisting of creeping stolon with rhizoid for anchoring on substratum, assimilators erect from stolon which bear various shapes of ramuli based on type of species. Some important species of *Caulerpa* are very distinct as their assimilators can take morphologically diverse shapes such as blade-like (*C. scalpelliformis* and *C. cupressoides*), pinnate or feather (*C. taxifolia* and *C. sertularoides*) like shape, where in ramuli grow in opposite direction and radial form in which ramuli grow in many direction around the central axes (*C. racemosa* and *C. microphysa*).

Many researchers have reported several species of *Caulerpa* from east and west coasts of India. These reports are however restricted to occurrences, distribution and some biochemical analysis of various species of *Caulerpa* *spp*. The detailed comparative morphological aspect although was not exercised before. Since this genus contributes to the largest amount of the total biomass, the present study was to enhance the understanding of various species of *Caulerpa*, their morphological variations, comparing these variations of the species collected from various locations in northwest coast of India.

**Materials and Methods**

Different species of *Caulerpa* were collected during lowest tide mark from intertidal area of Maharashtra, Malvan (lat. 16° 03’ 37.5” N, long. 73° 27’ 21.4” E), Colaba (lat. 18° 54’ 15.0” N, long. 72° 48’ 08.5” E) and Gujarat Veraval (lat. 20° 54’ 33.7” N, long. 70° 21’ 06.0” E), Okha (lat. 22° 28’ 48.2” N, 69° 04’ 50.9” E). All specimens were collected from exposed areas of intertidal region during lowtide. The collected samples were cleaned of attached debris, other foreign matter and brought to lab. Morphology of the specimen was examined, photographed, herbariums prepared and samples preserved in sea water containing 5% formaldehyde. During collection, care was taken to prevent the breaking of thallus, however due to strong adherence of species there was breaking of stolon, but this has not caused damage to the whole plant morphology.
Morphological measurements were recorded for assimilators height, width, spacing and numbers per 2 cm of stolon, branchlets type, width of disc/ramuli diameter, length of stalk, ramuli length and width, stolon diameter and rhizoid length, type and numbers per 2 cm of stolon. Height of assimilators is measured from the base arising on stolon. Stem and leaf plot\(^1\) (using SPSS. Version 16.0. Chicago, SPSS Inc) for height of assimilator and stolon diameter in collected species is given Figures 1 and 2.

**Result and Discussion**

A total of eight species and one variety form collected from Malvan, Colaba, Veraval and Okha were identified as *Caulerpa parvula* Svedelius, *Caulerpa peltata* Lamouroux and *Caulerpa taxifolia* (Vahl) C. Agardh from Malvan, *Caulerpa peltata* and *Caulerpa sertularoides* (S.G. Gmelin) M.A. Howe from Colaba, *Caulerpa racemosa* (Forsskal) J. Agardh, *Caulerpa racemosa* (Forsskal) J. Agardh v. macrophysa (Sonder ex Kutzing) Taylor, *Caulerpa microphysa* (Weber van Bosse) J. Feldmann, *Caulerpa scalpelliformis* (Brown ex Turner) C. Agardh and *Caulerpa veravalensis* Thivy & Chauhan from Veraval. *C. racemosa*, *C. sertularoides*, *C. taxifolia*, *C. scalpelliformis* and *C. veravalensis* from Okha (Plates I and II). Their occurrence along the west coast is given in Table 1.

**Morphological description**

Morphology of seaweed is mainly influenced by the habitat they are dwelling and the existing competition for available space. In case of intertidal species the environment is harsh, and has to resist the physical force of breaking wave, submergence during high tide, exposure and desiccation during low tides. Species belonging to genus *Caulerpa* are known to modify their morphologies in response to prevailing environmental conditions, which helps in species colonisation was reported by Ohba and Enomoto; Calvert\(^12,13\). Thus, morphological studies helps in understanding the adaptation of seaweeds to various conditions of environment they live in, identification of species and establishing source of origin in case of invasive species\(^14,15\).

The genera *Caulerpa* has been recognised as invasive species and studies have been done regarding various aspects of the species belonging to this genus\(^16-18\).

Assimilators are the primary parts of algae where photosynthesis takes place, *Caulerpa* genus has a diverse shape of assimilators which arise from stolon and extends towards surface\(^11,19\). Morphological comparisons between collected *Caulerpa* species and variation in assimilator height among studied species are shown in Table 1 and Fig 1 respectively. *C. parvula* (Plate IA) was collected from Malvan and its assimilator height ranged from 13.3 to 24.7 mm, similar results were reported in earlier studies on *C. parvula* where assimilators known to reach a height up to 40 mm in Gujarat and Sri Lankan waters which are only few areas from where the species has been reported\(^20,21\).* *C. peltata* (Plate- I B) was collected from two sites viz Malvan and Colaba; and height of assimilators recorded was 12.4 to 25.6 and 21 to 31.5 mm respectively. In Kenyan coast\(^22\) and in Thailand\(^23\) species is known to reach up to 50 mm height. Species *C. racemosa* (Plate- I C) was collected from Veraval and Okha sites and its assimilator height ranged from 24.6 to 33.5 mm and 28.4 to 48.2 mm respectively. *C. racemosa* v. macrophysa (Plate- I D) variety form of *C. racemosa* was collected only from Veraval and its assimilators height ranged from 12.1 to 18.1 mm. *C. microphysa* (Plate- I E) was also collected only from Veraval with its assimilators extending from 10.6 to 23 mm, in Philippine\(^24\) the species in known to reach upto 15 mm; this difference may be due to protection the algae got from wave action in Veraval as specimens collected mainly behind rocks or associated with larger forms of algae which gave shelter.

Plate I showing, A: *Caulerpa parvula*, B: C. peltata, C: *C. racemosa*, D: *C. racemosa* v. macrophysa and E: *C. microphysa*
II B) collected from Malvan, while the same species collected from Okha measured a maximum of 114.2 mm. This may probably be due to Malvan sample being collected from a comparatively wave protected area behind boulders while Okha samples were exposed directly to the wave action. Assimilators of *C. scalpelliformis* (Plate-II C) collected from Veraval measured up to 147.6 mm, while Okha samples up to 103.8 mm, and *C. veravalensis* (Plate-II D) from Veraval and Okha reached up to 45.5 mm and 73.4 mm height respectively.

The height of assimilator is restricted by the wave action which causing dislodgment of assimilators, as larger size increases surface and this increases susceptibility of assimilators to drag due to the wave surge. In similar studies from Sri Lankan waters, the height of *C. taxifolia* is recorded up to 250 mm and 600 mm in Mediterranean sea* C. scalpelliformis* has assimilator with a distinct blade shape and in the present study recorded widest reaching upto 16.1 mm, similar studies on the species in Turkey reported upto 13 mm wide assimilators. Ramuli are arranged opposite to one another on the assimilators of *C. sertularoides* (Plate-II A) and *C. taxifolia* (Plate-II B) which gives feather like appearance. *C. taxifolia* collected from Malvan had long assimilators (271 mm) and Okha specimen had widest (13.4 mm). The difference may probably be due to habitat variation, as Malvan specimens being collected from a relatively wave protected area, allowing the assimilators to grow taller and thinner, while as Okha specimens has to restrict height and increase in width.

Density of assimilators arising on stolon gives mat like appearance to the various species of genus *Caulerpa*. Number of assimilators arranged on stolon shows that shorter forms have highest numbers as in case of *C. microphysa* (5.89), *C. parvula* (4.85), *C. racemosa* (4.13 Okha and 3.87 Veraval) and *C. racemosa v macrophysa* (4), these species which form dense contiguous mats on the substratum which are growing. While species such as *C. sertularoides*, *C. taxifolia* and *C. scalpelliformis* density also form mats when grown densely as these species are having long constricted assimilators which overlap on one another.

Plate II showing, A: *C. sertularoides*, B: *C. taxifolia*, C: *C. scalpelliformis* and D: *C. veravalensis*

*Caulerpa* genus has various types of branchlets arranged in many ways on assimilator and is one of the main distinguishing characters for species identification. In the present study species consist of different shapes of branchlets like peltate (*C. parvula* and *C. peltata*), pinnate like (*C. taxifolia* and *C. scalpelliformis*).
serrularoides, C. taxifolia and C. veravalensis), grape or globular like (C. racemosa, C. racemosa v macrophysa and C. microphysa). Disc width of C. peltata ranged from 4.1 to 5.8 mm (Malvan) and 4.6 to 6.6 mm (Colaba), this observation is agree with earlier report on the species in Samiani Island\textsuperscript{20} (3 to 8 mm), Sri Lankan\textsuperscript{19}, Kenyan\textsuperscript{22} and Samoan Archipelago waters\textsuperscript{32} (3 mm). Ramuli of C. racemosa, C. racemosa v macrophysa and C. microphysa are round forms, C. racemosa v macrophysa was recorded up to 3.2 mm diameter similar observations were also been reported in other studies in Gujarat\textsuperscript{20}.

Okha 7 to 8.5 this increased length has resulted in increased width of the assimilator, similar studies have reported up to 10 mm length in Thailand\textsuperscript{21,23}. Width of ramuli in C. taxifolia ranged between 1 to 1.2 mm (Malvan) and 1.3 to 1.6 (Okha), ramuli were flattened, curved upwardly which gives a shekel shape with tapering ending\textsuperscript{20,21}. Ramuli length of C. veravalensis recorded up to 7.7 mm (Veraval) and up to 5.2 mm (Okha) while other works reported up to 7 mm in Papua New Guinea\textsuperscript{31}.

Stolon diameter differs from species to species ranging from 1.4 mm in C. peltata and C. serrularoides to 2.6 mm for C. scalpelliformis as shown in Stem and Leaf plot (Figure 2). This differs in Kenya\textsuperscript{27} and Turkey\textsuperscript{30} (1.5 mm for C. scalpelliformis). In Sri Lanka\textsuperscript{21} and Papua New Guinea\textsuperscript{31}, the thickness was reported up to 2 mm in C. peltata and C. veravalensis respectively.

Rhizoids are structures of attachment which arise from stolon and attaches to the substratum, which gives anchorage to the marine algae. In present study, two types of rhizoids pillar and thin were recognised\textsuperscript{15}, these kind of studies on rhizoidal forms important taxonomical characteristic for the genus and can be used in identification of the Caulerpa species. Thin type of rhizoid was observed in C. parvula, C. peltata, C. microphysa and C. veravalensis, while pillar type in C. racemosa, C. racemosa v macrophysa, C. serrularoides, C. taxifolia and C. scalpelliformis species under study.

**Conclusion**

These results indicate that Caulerpa species have same basic morphology compared to other such studies. However, distinct variation in morphometric measurements observed in present study, when related with earlier reports for genus Caulerpa can be attributed to its adaptive nature towards the prevailing environmental condition.

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Table 1: Comparison of morphological characters between different *Caulerpa* species (in mm).

<table>
<thead>
<tr>
<th>Species</th>
<th>Assimilators</th>
<th>Branchlets</th>
<th>Stolon Dia</th>
<th>Rhizoid</th>
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<tbody>
<tr>
<td></td>
<td>Height</td>
<td>Width</td>
<td>Spacing</td>
<td>No’s per 2cm stolon</td>
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<td>C. parvula (Malvan)</td>
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<td>3.6-8.7</td>
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<td>1.4-6.4</td>
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<td>1.1-19.2</td>
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