III - RESULTS AND DISCUSSION

A : ALGAE AT MALVAN

Malvan is the unique station just a crow fly distance (150 km) away from Kolhapur, situated on North latitude 16.03′ and East longitude 73.28′ on the West coast of Maharashtra, India (Fig.1). The substrata at Malvan is composed of laterite and granite rocks with upper littoral sand cover. This habitat receives poor to moderate exposure and mainly without any disturbances. Thus it is ideally suited for the development of luxurient algal vegetation. Moreover, for a marine phycologist this station can be considered as a paradise of algae (Plate 1) and hence selected for studying ecophysiological aspects of some representative types of algae.

1) Collection spots at Malvan :

The algal collection spots at Malvan have shown in Figure 2 from which most of the algal specimens were collected. These spots are named as A, B, C, D, E and F. Spot 'A' which is situated near Rajkot has a rocky intertidal zone with rich algal flora. The dominant algal specimens found over here include Ulva, Chaetomorpha, Caulerpa, Sphacelaria, Saragassum, Hypnea and Ceramium. The association of these algal members however, found to be different. As we proceed facing sea, the first alga which appeared was Ulva followed by a red alga Ceramium which was associated with a green alga Chaetomorpha. The brown alga

PLATE

PLATE 2

PLATE 3

PLATE 4

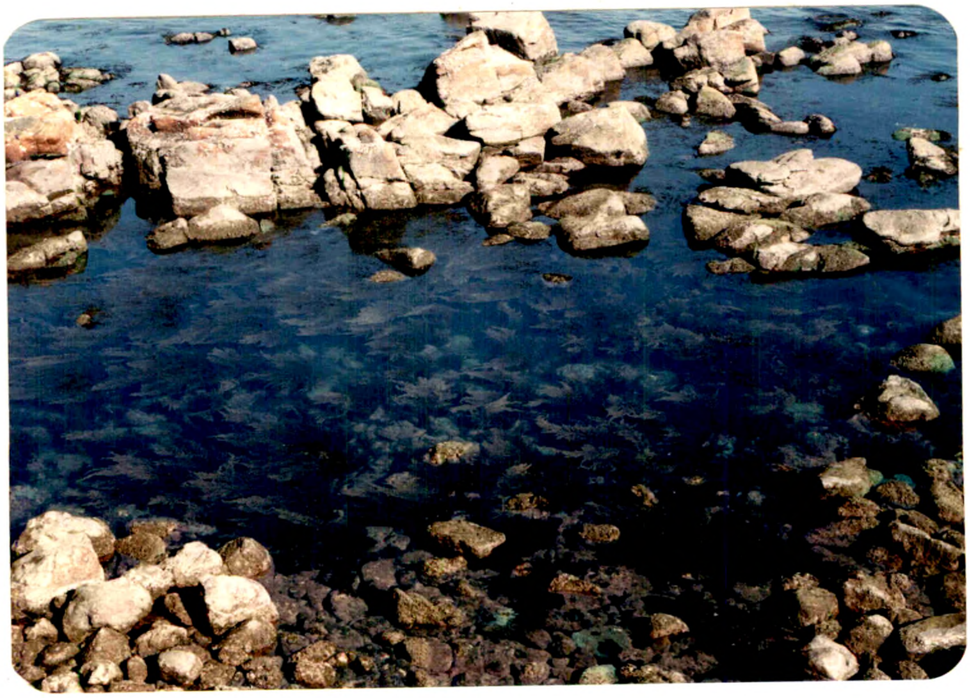


PLATE 5

Gracillaria corticata growing on rocky substratum at spot 'F'

Gracilaria

PLATE 6

Plate - 6. Close view of *Ulva fas~~s~~ciata* Delile, X ?

scale

PLATE 7

Plate - 7. Close-up of *Chaetomorpha media* (Ag.) Kutz.,x ?

scale

PLATE 8

Plate - 8. Close-up of *Sphacelaria furcigera* Kutz. , x ?

PLATE 9

Plate - 9. Close-up of *Dictyota dichot~~a~~oma* (Huds.) Lamour,

x ?

PLATE 10

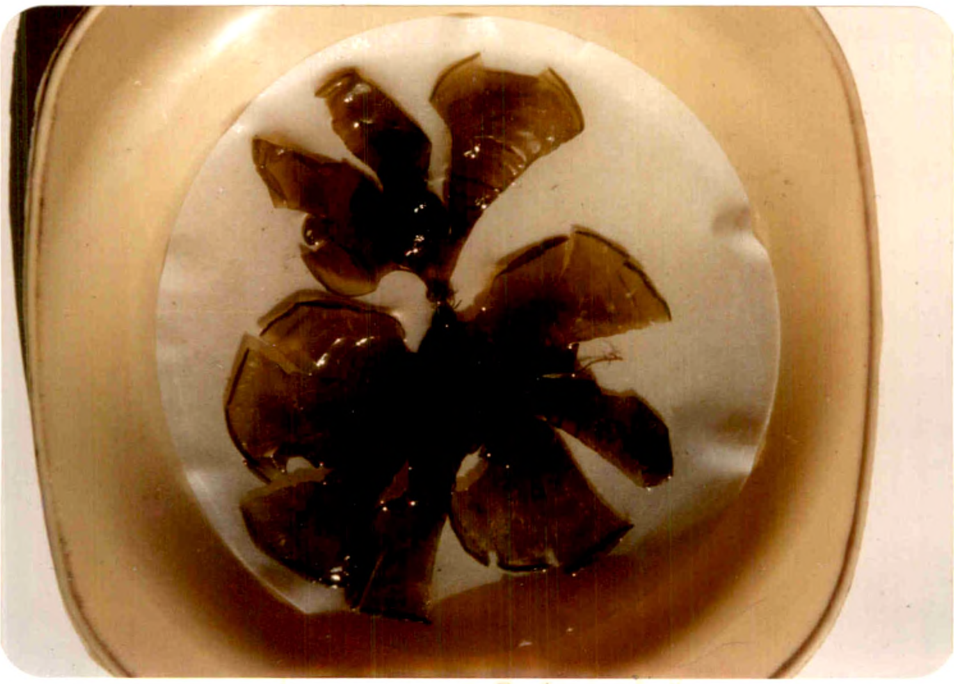


Plate - 10. Close-up of Padina tetrastromatica Hauk., x ?

scale

PLATE 11

Plate - 11. Close-up of Ceramium rubrum (Huds) C.Ag. , x

scale

PLATE 12

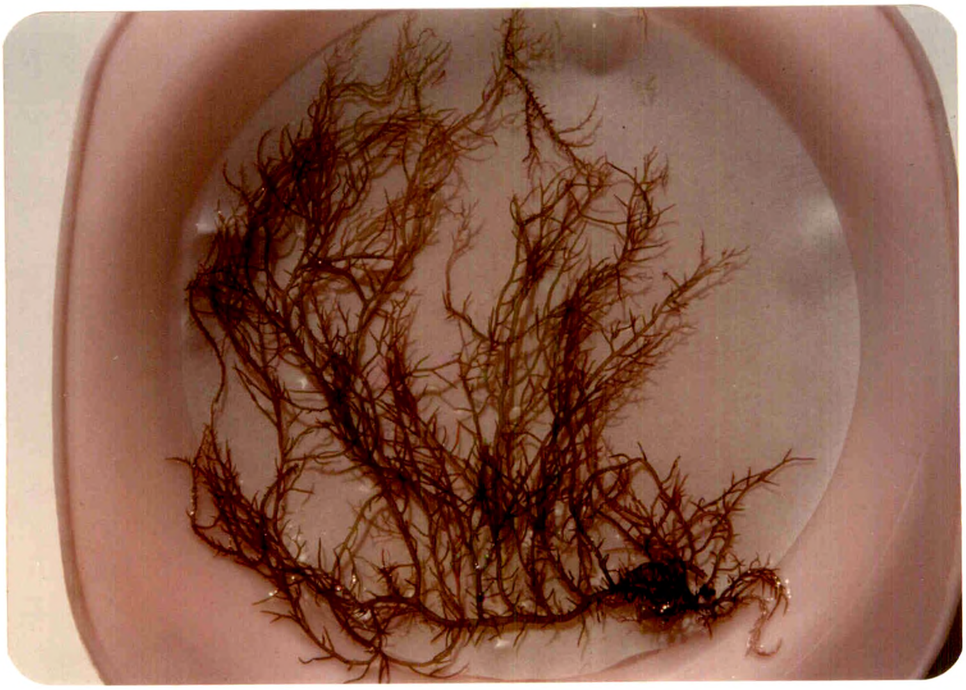
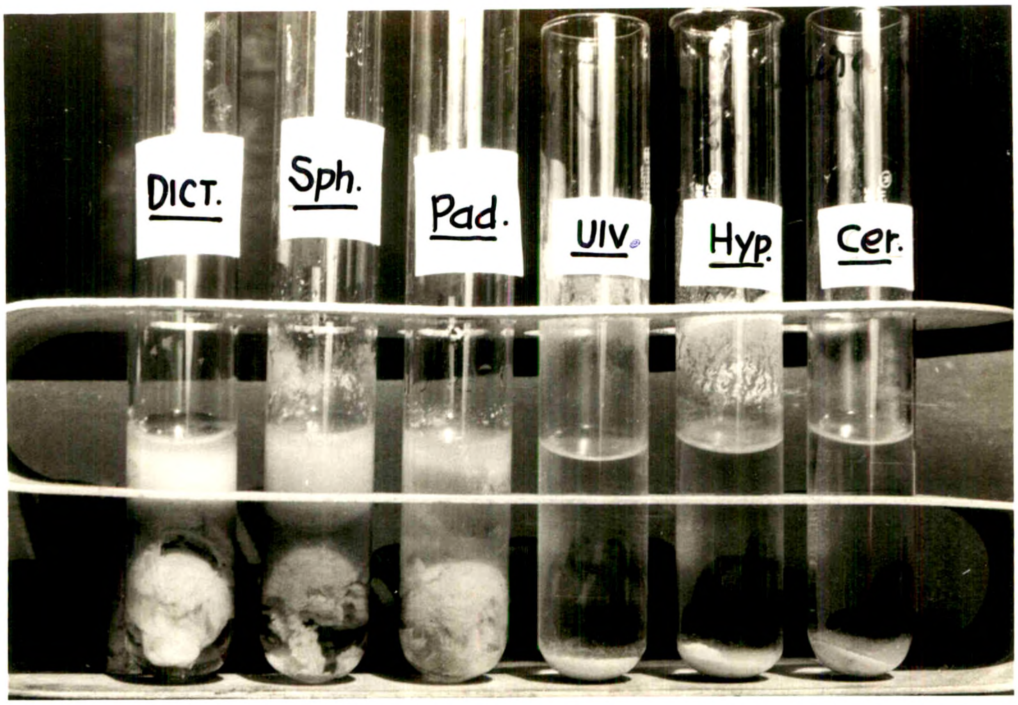


Plate - 12. Close-up of *Hypnea valentiae* (Turn) Monk., X ?
scale

PLATE 13.



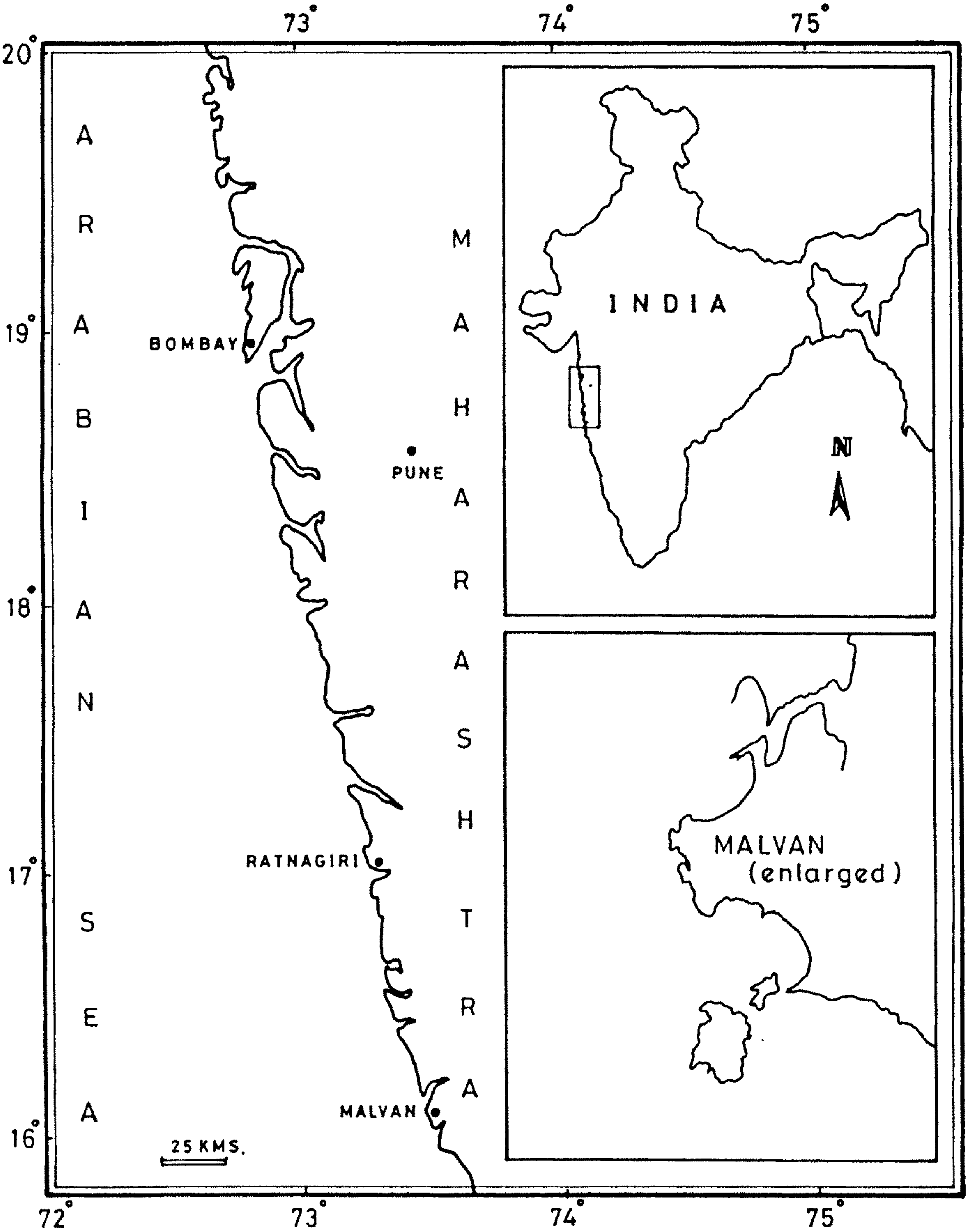

73°
74°
75°
20°
19°
18°
17°
16°
72°
73°
74°
75°
ARABIAN SEA
MAHARASHTRA
BOMBAY
PUNE
RATNAGIRI
MALVAN
25 KMS.
INDIA
N
MALVAN
(enlarged)

FIG. 1

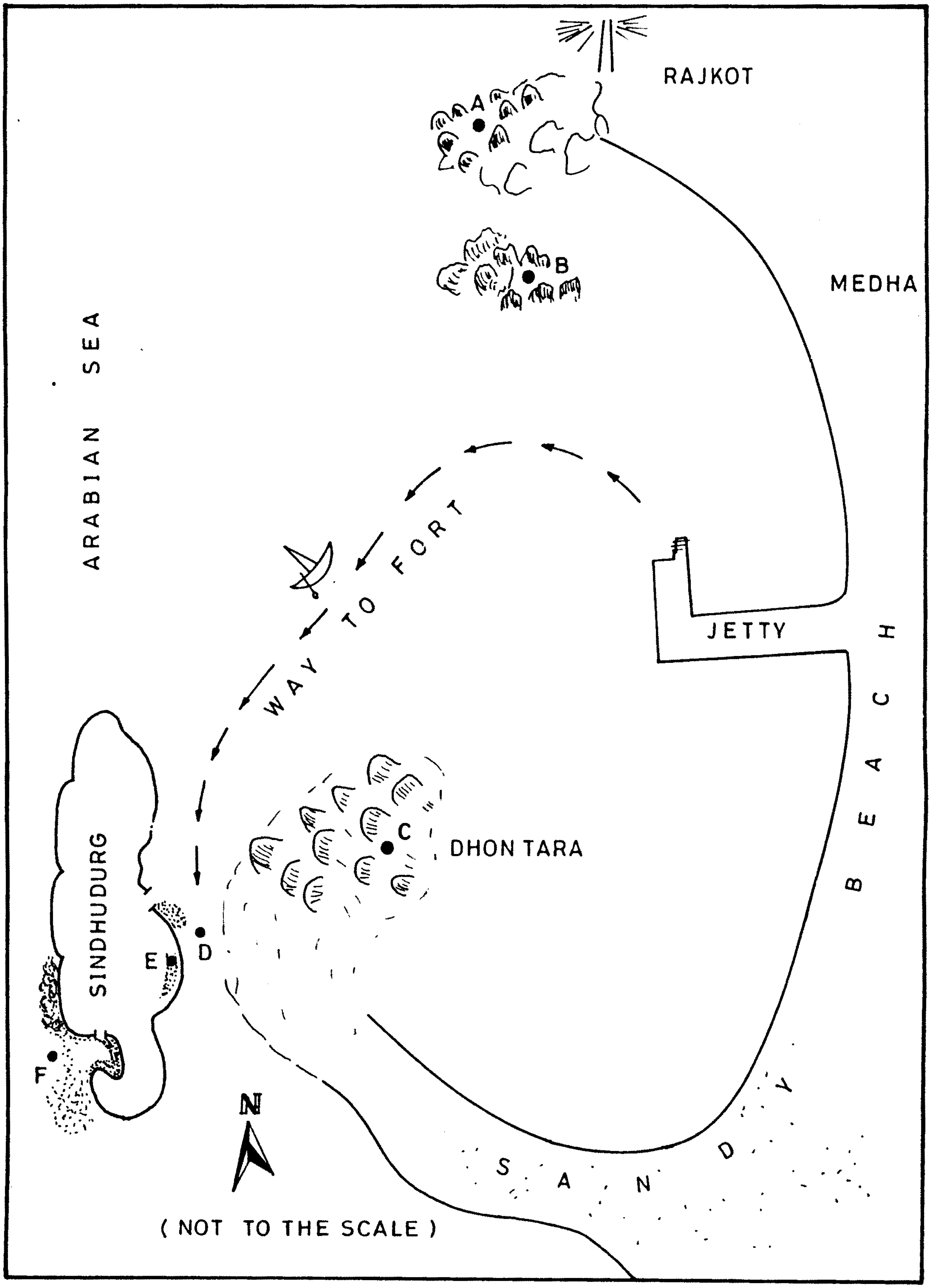

RAJKOT
A
B
MEDHA
ARABIAN SEA
WAY TO FORT
JETTY
BEACH
C
DHON TARA
SINDHUDURG
D
E
F
N
SANDY
(NOT TO THE SCALE)

FIG. 2

Sphacelaria was also associated with Chaetomorpha. This patch of algae was followed by a thick luxurient growth of a young thalli of Saragassum. Next to Saragassum a beautiful patch of different species of Caul~~u~~erpa, and finally a dense growth of a red algae Hypnea and Gracillaria were observed.

At spot 'B' which is in the vicinity of Medha has both sandy as well as small rocky substrata. On this rocky substratum we could collect Hypnea, Dictyota & Padina.

The spot 'C' located just in front of Sindhudurg locally known as "Dhontara" is full of rock boulders. On these rocky substrata dominant algae found were Padina, Dictyota, Hypnea, Gracillaria and Saragassum. Among these, Padina exhibited dense population at this spot.

The spot 'D' has sandy substratum with few rock boulders on which Padina and Dictyota were pre-dominant.

The spot 'E' which is located just inside the wall of the Fort has sandy substratum on which a thick mat of Enteromorpha was observed. No other alga was found at this spot.

The spot 'F' is located at South-West of the Fort facing towards the sea has full of rock boulders. On these bathing rock boulders several members of algae were noticed. These include species of Caulerpa, Bryopsis, Chaetomorpha, *Padina*, *Dictyota*, *Dictyopteris*, *Stoechospermum*, *Ulva*, *Sargassum*, *Hypnea*, *Gracilaria*, *Amphiroa* etc.

Balkrishan *et al*. (1974) and Joshi (1976) have also made extensive study of algal forms at Malvan. They have enlisted about 37 algal species (Table 2).

Table - 2 : Algal species at Malvan (After Joshi, 1976)

Class - Chlorophyceae

1) *Ulva fasiata* Delile
2) *Enteromorpha tubulosa* Link.
3) *Chaetomorpha media* Kutz.
4) *Caulerpa racemosa* (Forssk.) W.V. Bosse.
5) *Caulerpa racemosa* var. *Chemnitzia* (Esper.) W.V. Boose.
6) *Caulerpa racemosa* var. *Peltata* (Lam.) Eubank
7) *Caulerpa racemosa* var. *Uvifera* W.V. Boose.
8) *Caulerpa crassifolia* (Ag.) J. Ag.
9) *Caulerpa scalipeliformis* (R.Br.) W.V. Boose
10) *Caulerpa sertulariodis* (Gmel.) Howe.
11) *Caulerpa taxifolia* (Vahl) Ag.
12) *Caulerpa verticillata* J. Ag.
13) *Struvea delicatula* Kutz.
14) *Rhizoclonium tortuosum* (Farlow) Macclatchie
15) *Bryopsis pennata* Lamx.

Class - Phaeophyceae

16) *Sphacelaria* *furcigera* Kutz.

17) *Dictyopteris* *woodwordi* (Brown) J. Ag.

18) *Spathoglossum* *asperum* J. Ag.

19) *Pocockiella* *variegata* (Lom.) Papenfuss.

20) *Padina* *tetrastromatica* Hauck. ?

21) *Dictyota* *bartayresiana* Lamour

Class – Rhodophyceae

22) *Amphiroa* *frugilissma* (L.) Lam.

23) *Chondria* *armata* (Kutz.) Okamura

24) *Gratloupia* *filicina* (Wulf) J.Ag.

25) *Jaina* *rubens* (L.) Lamour.

26) *Halymenia* *delatata* Zanard

27) *Cheilosporum* *spectabile* Harvey.

28) *Catenella* *repens* (Light f.) Balt.

29) *Gracilaria* *corticata* J. Ag.

30) *Hypnea* *musciformis* (Wulf) Lamour.

31) *Hypnea* *valentiae* (Turn) Monk.

32) *Gelidium* *pusillum* (Stackh) Lejolis

33) *Agardhiella* *robusta* (Grev.) Boergs.

34) *Spyridia* *filamentosa* (Wulf) Harv.

35) *Lophocladia* *lallemandii* (Mont.) Schmitz.

36) *Acanthophora* *deliei* Lamour.

37) *Centroceros* *clavalatum* (Ag.) Mont.

This clearly indicates that algal flora at Malvan is very rich both qualitatively as well as quantitatively. From the collection spots mentioned in Fig.1 and described above, the dominant algal members belonging to class chlorophyceae, phaeophyceae, and rhodophyceae were selected for the present investigation. These algal members are tabulated in Table 3. The identification of these algae were confirmed by looking into the literature and with the courtesy of Dr. Vijaya Kerakar, Department of Botany, Goa University, Goa.

Table 3 : Algae selected for the present investigation

Division	Class	Name of the algae
Chlorophycophyta	Chlorophyceae	1) _Ulva_ _fasciata_ Delile
		? 2) _Chaetomorpha_ _media_ (Ag.)Kutz — See table on p.45 for authority
Phaeophycophyta	Phaeophyceae	? * 3) _Dictyota_ _dichotoma_ (Huds.)Lamour
		4) _Sphacelaria_ _furcigera_ Kutz.
		5) _Padina_ _tetrastromatica_ Hauk. ? see p. 46
Rhodophycophyta	Rhodophyceae	6) _Hypnea_ _valentiae_ (Turn) Mont. ? see p. 46.
		7) _Ceramium_ _rubrum_.(Huds.) C.Ag.

* did you collected it at Malvan?

2) *Description of algae and their seasonality at Malvan :*

a) *Ulva fasciata* Delile

The green alga *Ulva fasciata* popularly known as Sea Lettuce, is cosmpolitan in its occurrence, and is widely distributed in many parts of the world in the tropical and subtropical belts. At Malvan, it forms luxurient growth on small coralline pieces of rocks, on rocks and stones as large expansions of green, membranaceous sheets on exposed shore between tide marks, and nearer low tide level (Plate 6).

The plants initially attached, latter on at times may be detached and drifting in broadly expanded and torn sheets. The holdfast is very small and incospicuous. The thallus is foliaceous membranaceous, expanded plane, reaching up to 18 cm tall, obovate in young conditions. Margin of thallus ruffed, wavy and folded. The colour of thallus is bright green to light green, fading to yellowish and sometimes darker when young. Thallus lobes varying in thickness, 40–45 μ at margins, midportions 60–65 μ, one cell thick. The cells are uninucleate. The chloroplasts are cup shaped and filling outer third of a cell. Plants closely adhere to paper on drying.

The larger thalli sometimes get torn and get detached and these fragments float as loose living communities, vegetatively reproducing also. The plant is annual and seasonal in its occurrence. In dry summer months of the year, they are conspicuously absent from many situations.

b) Chaetomorpha media (Ag.) Kutz.

The green alga C. media was found attached to hard rocky and similar substrata, dense, tufted, brush-like filamentous, unbranched, errect stiff and rigid below, flexous above. It is usually 4-10 cm high, occasionally to 20 cm or more. Rhizoids well developed, vigorous branch system, horizontally spread out on substrata, irregularly ramified branches, branches ending in small coralliform irregularly shaped discs by which the plants are fastened to rocks and other substrata; rhizoids swell up here and there filled with starch, ultimately giving new shoots from them. Vegetative filaments above basal cell, cylindrical, barrel shaped, 400-550 μm broad; length of cells varies, 1-4 times or 5 times the breadth, cell wall lamellate, 60 μm thick. The colour is fresh green or dark green. Plants on drying adhere well to paper.

The green alga pictured here (Plate-7) is common in the tropical waters. At Malvan the alga was found growing luxuriently on quite exposed rocks and artificial rocky constructions, on the vertical faces, which are constantly dashed by violent breakers, and wetted by overthrow of huge quantity of water and in spray zones. In these much exposed localities, the plants are stunted, with the filaments broken or cut off at their upper ends, but very robust and healthy. The free extremities of these filaments appear colourless, obviously because of the escape of zoospores or gametes, the cells producing them being ultimately depleted of the contents. Associated with this alga is another interes~~d~~ting brown sea-weed Sphacelaria.

Seasonal activity of Chaetomorpha is well seen at Malvan. During September and October, the alga is seen in various stages of development, from young tufts to well developed ones. In November-December, the alga extends over a large area. In February the plants become much stunted and are found only scattered here and there. By March, the alga disappears from many areas where they were luxuriently growing, and whatever left appears only as very tiny, unhealthy tufts of a few mm height. In April, the growth becomes very poor and very much restricted, and in the following of May, the plants become poorer still and disappear almost completely. In July, with the onset of monsoon, fresh shoots start growing in several places.

c) Sphacelaria furcigera Kutz.

The brown alga S. furcigera (Plate 8) found at Malvan grows luxuriently on rocks, rock boulders, artificial constructions and on wooden materials like boats. At Malvan it was found growing in association with Chaetomorpha media also. It grows attached to rocks, or other algae, by means of a small more or less disc shaped holdfast. One or more freely branched cylindrical shoots arise from the holdfast. Each branch terminates in a conspicious, uninucleate, cylindrical, apical cell. Division of apical cell is by transverse. Derivatives two to four cells posterior to the apical cell divide and redivide in a vertical plane to form a transverse tier of 4 to 20 vertically elongate cells. Branching of shoots is due to enlargement of cell in the polysiphonous portion and it functions as an apical cell. Vegetative cells of *Sphacelaria furcigera* contain a single large nucleus and many small disciform chromatophores.

Sphacelaria furcigera has an alternation of generation. It reproduces vegetatively by means of propagules. Development of propagulum begins in the same manner as that of a lateral branch, but, after it has become a few cells long there is a vertical division of the apical cell into two or three daughter cells. Each daughter cell is the initial of a branch. The bi or triradiate branch system at the apex of a propagulum may remain short and massive, or become long and slender. Eventually there is an abscission of the propogulum at the point where it is attached to the thallus. It floats away, lodges upon a favourable susbtratum and then developes into a new thallus.

d) Dictyota dichotoma (Huds.) Lamour. (c)

The brown alga D. dichotoma is inhabitant of warm water seas. It is world-wide in its distribution. It grows in permanently submerged situations and normal habitat is probably in water of some depth. At Malvan, Dictyota is found in rock-pools between tide-levels and it is evident that, it can exist in a variety of situation.

Dictyota dichotoma, the commenst British representative, is a widely distributed annual. The familiar forked fronds as pictured here (Plate 9) all branches of which are normally situated in the same plane, arise from a cylindrical rhizome attached to the substratum by tufts of sometimes branched rhizoids. These can also develop from cells of the flat thallus, which is sometimes partly prostrate and attached. The lower part of the erect fronds is like wise cylindrical and commonly gives rise to adventitious laterals, some of which may develop as horizontal stolons. Both the lower cylindrical parts and flattened fronds, into which they gradually expand, grow by means of a single apical cell which, when viewed from above, appears circular in the cylindrical and elliptical in the flattened portions. On the broader fronds the apical cell is often slightly sunk, but when the thallus is more finely divided the segments gradually narrow to the apical cell.

The mature thallus thus comes to consists of three layers, a middle one of large cells with few or no chromatophores bounded by layers of small cells, densely packed with chromatophores. The central cells contain, apart from fucosan vesicles, conspicuous groups of large refractive globules which are suspended by cytoplasmic strands; they appear to constitute some kind of food-reserve, and are stated to be responsible for the iridescence commonly exhibited by this alga. The rather thick walls separating the cells possess conspicuous pits. Tufts of colourless hairs, with the usual basal meristem, are scattered over both surfaces of the thallus, but are shed during the reproductive phase.

Dichotomy is effected by longitudinal division of the apical cell in to two equal halves, the classical instance of such branching. Adventious lateral, which develop from single marginal cells and expand in the same plane as rest of the thallus, are not uncommon; they tend to arise especially at points of injury and, after death of parent, become independent and constitute a profile source of vegetative reproduction. Pieces of thallus provided with an apical cell readily develop into new plants.

e) *Padina* *tetrastromatica* Hauck

The brown alga *P*. *tetrastromatica* is erect, in several clumps, several baldes arising from the same stupose basal attachment, 12-15 cm or more in height. Rhizome is prostrate branched, attached to substratum by tufts of rhizoids. Frond stalked, varying in size, numerous fan shaped to reniform, thin, flat, much lobed, some what plicate, the large blades loosely rolled on the longitudinal axis like a cornet, conspicuously concentrically zonate. Blades frequently split into numerous narrow segments, lower portions of segments attenuate; segments 1-2 cm broad. Zonation caused by rows of hairs and fructiferous organs in concentric zones, 0.5 mm broad in the blades. Hairs present on younger thallus; in older ones, either rudimentary or absent, hairs shedding when fructiferous organs develop. Fructification structures on both sides of the hairs, and through the length of the zone in the concentric ring, in definite arrangement in relation to hairs.

Cross section of the thallus in two layers of cells in younger parts, 3-4 layers of cells in older and basal parts. Colour of the plant is straw coloured to brown or dark, olive-green and reddish hues in older part; appears whitish also b/u due to thin encrustation of carbonate of lime. The alga adheres well to paper on drying.

<u>Padina</u> grows luxuriently at Malvan, in well sheltered as well as in much exposed localities near low water mark and below, in intertidal lagoons, rock pools, tranquil bays etc., at

mid-tide levels and lower, extending to upper limits of high tide mark, in favourable situations (Plate 10).

The brown sea-weed illustrated here goes by the popular name "The Peocock's tail" alga because of the peculiar structure of the blades with the series of concentric zones, on the thin, flat, fan shaped blades. The alga grows in situations where the boulders and other hard sdubstrata are smothered by thick sediments of very fine sand, which sometimes make the substrata slippary. The alga tolerates repeated submergence and constant agitation during high tide, followed by complete exposure and quiescence, and even certain amount of desiccation, during low tides. In January, the alga bears plenty of tetrasporangia along the concentric zones. The older parts of the plants are heavily loaded with epiphytes, and smothered by heavy deposit of slit. The common epiphytes are diatoms and _Ceramium_. Germination of tetrasporangia in situ is noticed in several cases, the young germlings still attached to parent plant thallus.

f) _Ceramium_ _rubrum_ (Huds.) C. Ag.

The red alga _C._ _rubrum_ occurs very commonly between tide levels and in deeper water being especially abundant along the Mediterranean coast. The richly branched uniaxial plant body is recognizable from the banded appearance and the tong-like forking of the apical region of the branches, these are considered very valuable diagnostic characters.

The alga *Ceramium rubrum* pictured here (Plate 11) grows luxuriently at Malvan on rocky substratum, artificial constructions and woody materials. It also grows as an epiphyte on other plants like *Padina*. The thallus when young is attached to the substratum by a cushion like structure, which with maturity develops in to rhizoids. The typical dichotomous branching is initiated by the forking of the dome shaped apical cell. The plant body is made up of a single row of large cylindrical or barrel shaped cells arranged one upon the other. The banded appearance of the filament is developed as a result of the formation of an envelope of small-celled cortical cells cut out from the central axial cell. This development of envelope is not continuous throughout the entire surface for which there results the banded appearance of the filaments. The colour of the plant body is extremely variable, may be red, yellowish green, or reddish-brown,*Ceramium* possess specialized diplobiontic forms in the life cycle.

g) *Hypnea valentiae* (Turn) Monk.

The red alga *H. valentiae* a uniaxial gigartinales is common in warmer seas and found elesewhere only in sheltered habitat. The *Hypnea valentiae* found at Malvan is luxuriently growing on rocky substratum (Plate 12). It commonly occurs between tide levels. The thallus is firmly attached to the substratum with the help of heptera. *Hypnea valentiae* has got fleshy terete thallus which grows up to 30-40 cm long with numerous short branches; many of the branches longer ones and are incurled at the tip and function as tendrils. The mature structure has uniform enlargement of the inner cells of the laterals. So that the axial cells remain clearly evident. Hairs are often abundant in well illuminated situation. Many times the thallus may cut off, and may be found as detached one.

Thus the observations made in different seasons for algal growth is indicative of the fact that algae start appearing in the month of July and most of the species grow luxuriently during September, October to March. The peak growth and biomass was generally observed during November-January, however, some species show variations in their periodicity of abundance. Algae start dwindling from March onwards as the summer climatic factors dominate intertidal areas, and disappear near the approach of South-West monsoon in early June. However, some algae were found to tolerate/adapt to different conditions round the year include *Ulva fasciata*, *Hypnea*, *Ceramium*, *Padina*, *Enteromorpha*. The overall observation of seasonality of algal growth at Malvan reveals that the green algae are dominant during September to December, brown algae in December to March and red algae in December to April. It is interesting to note here that

Sphacelaria and Chaetomorpha were more dominant in the month of September only.

B. HYDROLOGICAL PARAMETERS :

Growth and distribution of marine algal flora depends upon several factors such as topography, geological features, physico-chemical characters of water and biological factors (Agadi and Untawale, 1978). Therefore it is essential to study the hydrological data. Of the hydrological parameters like seawater temperature, pH, conductivity and nutrients (sodium, potassium and calcium) studied at Malvan show uniformity in their seasonal distribution (Table-30). It is clear from the Table that the temperature and conductivity values are lesser during the monsoon months, and later they increase gradually. It is known that tropical habitats have warmer temperatures with less seasonal variation than temperate areas. The change in the surface water temperature occurs by the variation in cloudiness, air turbidity and air temperature. The optimum temperature for seaweed growth reported to be 28^{0}-30^{0}C. (Agadi and Untawale, 1978). The temperature values of present investigation are very much in the range and possibly this may be one of the reasons which contributes for the luxurient growth of algae at Malvan. The conductivity values ranged from 37.13 to 57.1 having low level during post monsoon, and higher level during summer months.

Table - 39: Seasonal variation in pH, conductivity and some inorganic constituents of sea water at Malvan coast

Parameters	Post-monsoon	Winter	Summer	Average
Temperature (^{o}C)	28.5	29.8	30.5	29.6
pH	7.83	8.21	8.1	8.04
Conductivity (m mhos cm^{-1})	37.13	43.54	57.1	45.92
Sodium (g L^{-1})	12.8	11.3	10.9	11.66
Potassium (g L^{-1})	0.52	0.47	0.46	0.48
Calcium (g L^{-1})	0.65	0.55	0.57	0.59

The values are mean of three determinations.

Cryer (1976) has also reported distinct variations in the pH and conductivity of seawater. It is also evident from Table-3 that the nutrient level was higher during monsoon and gradually declined in winter and summer months.

pH of the medium plays an important role in growth and survival of algae. Shacklock *et al.* (1973) observed that the growth of *Chondrus crispus* was greater at pH 7.3 - 7.8 than that of 6.7. Devi Prasad and Chowadary (1979) were of the opinion that ? See p. 113 colonial green alga *Gloeotaenium* prefer alkaline pH ranging between 8.0 and 9.0. The aggrophytes *Gracilaria corticata* and ? *Gelidiopis gracilis* could thrive only under pH ranging between 7.0-8.0 (Singh *et al.* 1980). Our observations indicate that the pH range of seawater in different seasons is quite congenial for the growth of different algae.

C. CHLOROPHYLLS

Algae have evolved varioius pigments for the purpose of light absorption; these can be classified into three major groups. (1) Chlorophylls that strongly absorb blue and red light for example chlorophyll 'a' (present in all algae) and chlorophyll 'b' (present in green algae) (2) Carotenoids that absorbs blue and green light, for example β-carotene (present in all algae), Phycobilins that absorb green, yellow and orange light, for example r-phycoerythrin (present in red algae) and c-phycocyanin (present in blue green algae). These bulk pigments provide an antenne to the algae to capture the light energy (Govindjee and Braun, 1974).

Thus, chlorophylls are the master molecules which harness solar energy and also are the energy trapping pigments in the process of photosynthesis. Chlorophyll 'a' is the primary photosynthetic pigment in all oxygen evolving photosynthetic organisms including algae, but the other algal chlorophylls have a limited distribution and are considered as accessory or secondary photosynthetic pigments (Meeks, 1974). Hence chlorophyll contents of different marine algae was investigated and tabulated in Table-4.

It is evident from the Table that though chlorophyll 'a' is present in all algae its concentration varies. This can clearly be seen in Table-4. The chlorophyll 'a' content of chlorophycean members ranged between 40-50, in pheaophycean members it was in the range of 40-65, and in the rhodophycean members it was 19-28 mg 100^{-1} fresh weight. However, chlorophyll 'b' content was appreciably higher in Ulva fasciata and Chaetomorpha media as compared to phaeophycean and rhodophycean members. The low level of chlorophyll 'b' content in Ceramium rubrum and Hyphnea valentiae indicated that rhodophycean members

Table - 4 : Seasonal variations in chlorophyll content in different marine algae.

Algae	Chlorophyll 'a' PM	W	S	Chlorophyll 'b' PM	W	S	Total Chlorophylls PM	W	S	Chlorophyll a/b ratio PM	W	S
Chlorophyceae												
fasciata or fasciata <u>Ulva</u> <u>basicata</u> ?	49.8	51.5	40.5	51.3	57.1	45.0	101.5	108.6	85.5	0.97	0.90	0.90
<u>Chaetomorpha media</u>	40.84	49.10	39.0	40.66	43.50	38.0	81.5	92.6	77.0	1.0	1.12	1.02
Phaeophyceae												
<u>Dictyota dichotoma</u>	39.51	47.5	36.3	16.11	20.20	14.30	55.62	67.70	50.60	2.45	2.35	2.53
<u>Padina tetrastromatica</u>	89.55	95.3	70.80	23.34	28.60	19.30	112.89	123.9	90.1	3.83	3.33	3.66
f a <u>Sphacel~~o~~ria</u> <u>~~b~~urcigera</u>	64.30	75.0	50.40	21.92	26.48	16.36	86.22	101.48	66.76	2.91	2.83	3.08
Rhodophyceae												
<u>Ceramium rubrum</u>	27.92	35.20	24.30	11.44	15.20	8.60	39.36	50.4	32.90	2.44	2.31	2.82
<u>Hypnea valentiae</u>	18.77	26.40	13.50	8.15	12.10	6.6	26.92	38.50	20.1	2.30	2.18	2.04

Values are expressed in mg 100 g fresh wt.
and are mean of three determinations.

PM : Post monsoon,
W : Winter season
S : Summer season

are poor in synthesizing chlorophyll 'b'.

The highest total chlorophyll content was exhibited by Padina followed by Ulva, Sphacelaria and Chaetomorpha, however Ceramium and Hypnea showed less total chlorophyll content. The chlorophyll a/b ratio was higher in red and brown algae whereas it was kept at lower ebb in green algae. this is obvious because chlorophyll 'b' level was comparatively higher in green algae. It is also evident from Table-4 that all the marine algae show seasonal variation in the level of chlorophyll contents. The total chlorophyll was at highest peak during winter and was declined in summer months. Similar observation was made in Gracilaria by Liu et al. (1981). It is also interesting to note here that the chlorophyll values can positively be correlated with the level of magnesium in the algal tissue with slight variation here and there (Table-13). Such type of correlation was also shown by Liu et al. (1981) in Gracilaria. The reduction in the level of total chlorophyll in summer months mostly due to maturity of algae.

D. CAROTENOIDS

Carotenoids in algae are reported to have a number of functions in photosynthetic and phototactic organisms. By absorbing light in the region where absorption by chlorophyll is low and transferring this energy to chlorophyll, they increase

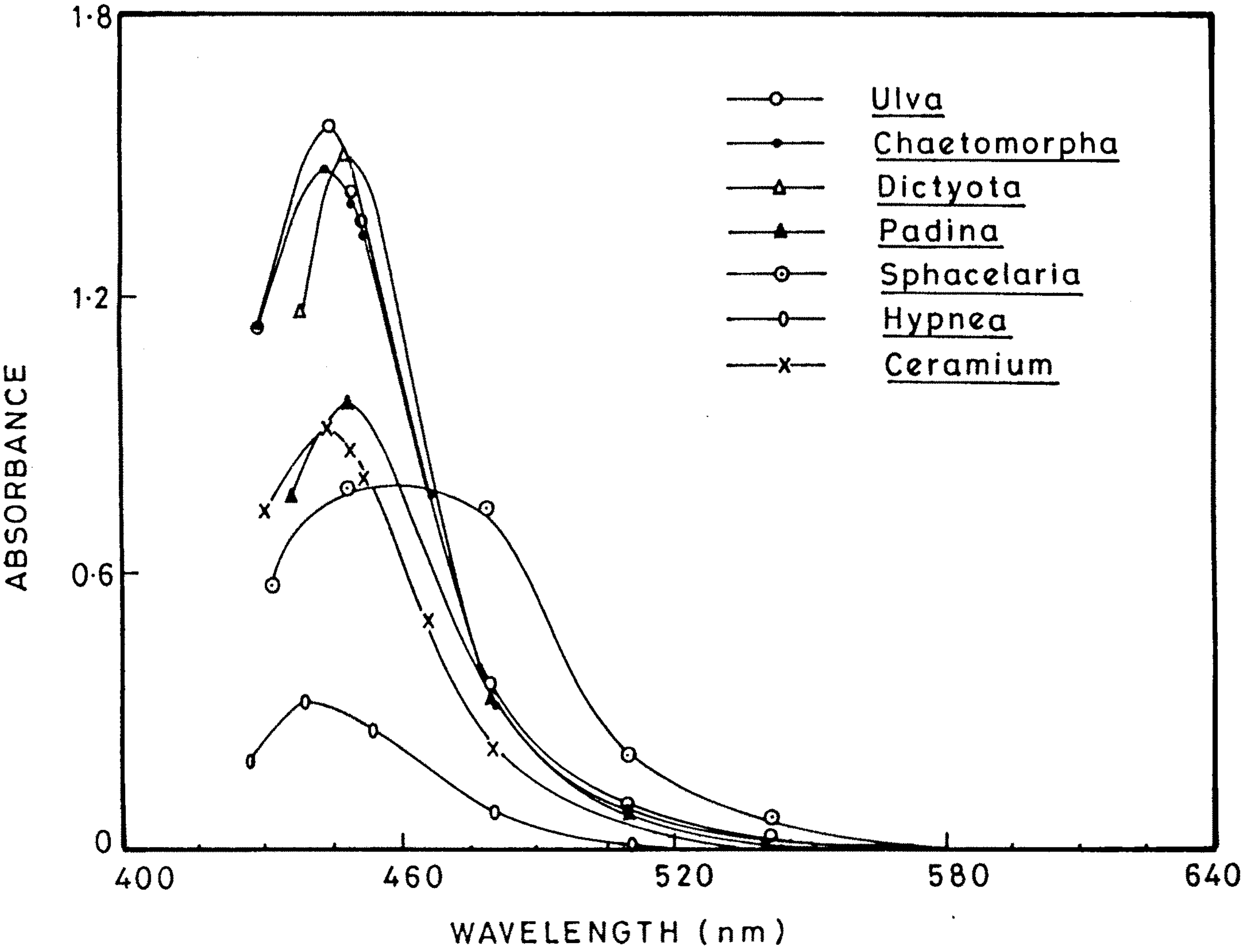

1·8
1·2
0·6
0
ABSORBANCE
400
460
520
580
640
WAVELENGTH (nm)
Ulva
Chaetomorpha
Dictyota
Padina
Sphacelaria
Hypnea
Ceramium

FIG. 3

the capacity of plants to gather light for photosynthsis (Blinks, 1954). Carotenoids also protect the cell from photodynamic destruction (Macmillan *et al.* 1966; Maxwell *et al.* 1966). It has also been confirmed that carotenoids play a role in the transport of the oxygen (Yamamoto *et al.* 1962). This has prompted us to study the carotenoid content of some green, brown and red algae of Malvan Coast.

the λmax for carotenoid was studied in saponified acetone extract, and represented graphically in Fig.3. It is clear from the figure that the λ max of carotenoids for all the algae was in the range of 425 to 460 nm and the maximum being at 450 nm. However the absorption of light by the carotenoids differ largely. *Ulva fasciata*, *Chaetomorpha media* and *Dictyota dichotoma* showed maximum absortpion, *Padina tetrastromatica*, *Sphacelaria furcigera* and *Ceramium rubrum* showed medium absorption while *Hypnea valentiae* exhibited comparatively less absorption at 450 nm. This indicates that the carotenoids of green, brown and red algae absorb more, moderate and less light respectively. It is noteworthy to mention here that *Ceramium rubrum* has absorbed more light as compared to *H. valentiae*.

The carotenoids content analysed in different green, brown and red algae is given in Table-5. It is vividly clear from the Table that *C. media* and *U. fasciata*, members of class

Table - 5 : Cartotenoids content of different marine algae

Algae	Carotenoids (mg 100^{-1}fresh wt.)
Chlorophycophyta	
Ulva fasciata	75.0 ± 3.5
Chaetomorpha media	67.0 ± 5.2
Phaeophycophyta	
Dictyota dichotoma	21.0 ± 2.0
Padina tetrastromatica	63.0 ± 3.1
Sphacelaria furcigera	55.0 ± 4.6
Rhodophycophyta	
Ceramium rubrum	23.0 ± 1.0
Hypnea valentiae	39.0 ± 3.0

chlorophyceae exhibit highest values of carotenoids as compared to rest of the brown and red algae. Among brown algae P. tetrastromatica and S. furcigera contained almost more than double the amount of carotenoids of D. dichotoma. The carotenoids content of red algae C. rubrum and H. valentiae ranged between 22 and 39 mg 100^{-1}g fresh weight.

The low level of carotenoids in D. dichotoma, C. rubrum and H. valentiae can very well be correlated with low level of total chlorophyll (Table-4). This reduction in chlorophyll content led us to surmise that possibly low level of carotenoids unable to prevent photodynamic destruction of chlorophylls (Macmillan et al., 1966).

E. MOISTURE, ASH, LIPID AND PROTEIN CONTENT

1) Moisture content :

The moisture contents of the tissues of different marine algae under prevailing conditions at Malavan ranged between 58.4 and 86.3%. The lowest value (58.4%) was noticed in the summer season, while highest value (86.3%) was found during winter season. It is evident from the Table-6 that moisture content increases from postmonsoon to early summer, and declines markedly in late summer. It is also evident that winter being a grand growth period of algae, exhibit higher moisture content. Our observations are in conformity with other workers.

(Joshi and Gowda, 1975; Kulkarni and Nimbalkar, 1981).

2) Ash content :

Maximum ash content is generally observed in algae when they reach climax of their life cycle or a grand growth period which can be evidenced from the values recorded in Table-6. The ash content studied in different marine algae reveals that the green algae Ulva fasciata and Chaetomorpha media have highest values, Dictyota dichotoma, Padina tetrastromatica and Sphacelaria furcigera have moderate values and Ceramium rubrum and Hypnea valentiae have exhibited comparatively low values. However, maximum ash content of all the algae was found during late monsoon and early winter, during which algae attains maximum growth.

Parekh et al. (1977) reported wide range of variation in ash content (23.5-77.78%) of green seaweeds. Since ash content appears to be good growth index, 5% change in ash content reflects two fold change in growth of algae (Lapointe, 1981). The variation in ash content was studied by many workers and are of the opinion that the range of ash content in the algae differ from place to place, and also from month to month (Parekh et al., 1977; Prince and Daly, 1981; Rao et al., 1983; and Penniman and Mathieson, 1987). It was also noted that different part of the

Table - 6 : Seasonal variations in moisture, ash, lipid and protein content of different marine algae.

• Algae	Moisture content % PM	W	S	Ash % PM	W	S	Lipid % PM	W	S	Protein % PM	W	S
Chlorophyceae												
Ulva basicata	72.47	75.5	69.6	30.5	34.1	28.6	0.75	1.6	0.60	13.50	15.80	11.21
Chaetomorpha media	79.46	83.6	76.3	35.5	37.9	32.6	0.80	1.96	0.78	6.43	8.93	5.20
Phaeophyceae												
Dictyota dichotoma	84.8	86.3	81.2	26.3	299.0	22.9	1.3	2.2	0.97	11.56	14.2	9.3
Padina tetrastromatica	78.44	83.1	74.6	22.3	25.1	19.3	1.7	2.9	1.01	9.63	12.41	7.42
Sphaceloria burcigera	62.09	66.8	58.4	20.1	23.2	16.4	1.5	2.3	1.0	5.5	8.2	5.1
Rhodophyceae												
Ceramium rubrum	70.38	72.6	69.2	17.5	20.2	15.3	0.87	1.7	0.79	18.6	21.6	15.2
Hypnea valentiae	81.06	84.8	76.8	21.5	24.3	18.6	0.43	0.8	0.35	14.68	18.6	12.9

Values are mean of three determinations.

PM : Post monsoon,
W : Winter season
S : Summer season

same plant vary in ash percentage (Kulkarni, 1980). The data given in table-6 strongly supports the above hypothesis. Neighbors and Horn (1991) have also studied ash content in different marine algae belonging to chlorophyta, phaeophyta and Rhodophyta. The values reported by them are very much alike to the values of present investigation.

3. Lipid content :

In order to establish nutritional quality of seaweed it is necessary to study the parameters such as ash, lipid, protein, nitrogen and carbohydrate contents (Neighbors and Horn, 1991). With this impetus in mind the lipid content analysed from different marine algae was incorporated in Table-6. The lipid content in green algae ranged between 0.6 - 1.96%. In brown algae it was between 0.97 - 2.9% and in red algae it fluctuated between 0.35 - 1.7%.

The values of lipid content reported by Neighbors and Horn (1991) for chlorophyta are in the range of 0.7 - 1.6%, for phaeophyta 0.4 - 1.7% and for rhodophyta 0.2 - 0.8%. These values tally very well with the values of present investigation. It is also evident from the Table-6 that the lipid content was more in phaeophycean members as compared with chlorophyceae and rhodophycean members.

4. Protein content :

The variation in protein level with respect to season is given in Table-6. The highest protein value was observed in *Ceramium rubrum* during winter season, and the lowest value in *S. furcigera* in summer season. The overall protein content was at maximum level during the winter season in all the algae. This clearly indicates that like that of ash and lipid content, protein values are also vary with varying seasons. Such type of observation has been reported by many workers (Kulkarni, 1980; Dhargalkar, 1986; Neighbors and Horn, 1991).

In general the data incorporated in Table-6 reveals that the nutritional parameters such as ash, lipid and protein levels were remained at higher ebb during early winter up to early summer, and inclined towards declination during late summer. This observation make us to argue that the harvest of algal material at Malvan should be done during post monsoon to early summer. However, it appears that each member has got its own mode of growth with respect to season. In this context it is necessary to analyse the dietary algae for nutritional aspect to fix the threshold harvest time. The work in this direction is in progress.

F. SUGAR CONTENT

The sugar content analysed from different marine algae

Table - 7 : Sugar content of different marine algae

Algae	Reducing sugar %	Insoluble carbohydrate* %	Soluble carbohydrate %
Chlorophycophyta			
Ulva	0.066	4.03	26.3
Chaetomorpha	0.042	3.16	18.1
Phaeophycophyta			
Dictyota	0.048	3.09	17.9
Padina	0.42	2.58	13.8
Sphacelaria	0.036	2.63	14.3
Rhodophycophyta			
Ceramium	0.030	3.48	21.8
Hypnea	0.049	3.41	21.1

* Represents sugar from residual matter after the extraction of soluble sugars and alginic acid.

collected at Malvan only during post monsoon season was analysed and the data is represented in the Table-7. The reducing sugar, insoluble carbohydrates and soluble carbohydrate level in *Ulva fasciata* was comparatively more than that of brown algae namely *P*. *tetrastromatica*, *D*. *dichotoma* and *S*. *furcigera*. This is mainly because, the photosynthetic area available was more for *U*. *fasciata*, as it was growing luxuriently. Overall, the carbohydrate values are in the range of 16-30%. Dhargalkar *et al*. (1980) and Untawale *et al*. (1982) have reported the carbohydrate content in seaweeds along Maharashtra coast which ranged between 17 and 46% and 41 and 67% respectively. Our values of carbohydrates more or less are in the same range i.e. 17 to 30%, but do not reach the highest peak as reported by the above workers. This may possibly because we have analysed the carbohydrate from the algae which were under early phase of growth. The picture will be more clear if we analyse the algae during late winter to early summer. As such the highest carbohydrate level was reported in winter season by many workers (Patil, 1967; Joshi and Gowda, 1975; Kulkarni, 1980; Untawale *et al*., 1982; Dhargalakar, 1986 and Penniman and Mathieson, 1987).

Thus it is very clear from the above discussion that the potentiality of algae can be judged very well by knowing specific time period during which they exhibit highest values of biochemical composition.

G. POLYPHENOLS :

A knowledge of the seasonal variation in the content of brown algal polyphenols could provide clues about the physio~~o~~logical role, if any, of these compounds, and could contribute to an understanding of their ecological significance. Similarly they play a significant role in the chemical ecology of the plant's defence system and hence seasonal variation in polyphenol contents of different marine algae was studied. The data is reported in Table-8.

It is very clear from the Table that the phaeophycean members are rich in phenolic content as compared with chlorophycean and rhodophycean members. Seasonality in phenolic contents also clearly indicated that their concentration was higher during winter season and it slowly comes down during early summer season and then accumulated again in the late summer (data not shown). The similar situation was observed in C. rubrum, H. valentiae and U. fasciata, with low polyphenol contents. Polyphenol contents of C. media during post monsoon and winter season were nearer to phaeophycean members, but in summer season the level of polyphenol was declined. This declination was almost half of the values registered by phaeophycean members.

Table - 8 : Seasonal variation in Polyphenol content of different marine algae

Algae	Polyphenols g 100^{-1} g dry wt		
	Post monsoon %	Winter %	Summer %
Chlorophycophyta			
<u>Ulva fasciata</u>	0.18	0.416	9.2
<u>Chaetomorpha media</u>	0.345	0.634	0.21
Phaeophycophyta			
<u>Dictyota dichotoma</u>	0.27	0.58	0.43
<u>Padina tetrastromatica</u>	0.375	0.98	0.76
<u>Sphacelaria furcigera</u>	0.24	0.61	0.46
Rhodophycophyta			
<u>Ceramium rubrum</u>	0.15	0.450	0.32
<u>Hypnea valentiae</u>	0.18	0.54	0.22

Values are mean of three determinations.

Rao and Untawale (1991) have also studied polyphenol content of 15 species of brown seaweeds, whose concentration ranged from 0.23 to 2.06% on dry weight basis. Ragan and Jensen (1978) have studied seasonal variation in polyphenol content of *Ascophyllum nodusum* and *Fucus vesiculosus* and reported that the content of polyphenols in *A. nodusum* was at minimum during the period of maximum fruit body in late May, and reached maximum during the winter season. In *F. vesiculosus* the minimum was just before the period of fertility and thereafter rose to a maximum during the period of sterility.

Further they have reported that the phenolic compounds interfere with alginic acid extraction procedure, hence it is essential to establish a correlation between alginic acid and phenolic compounds in order to exploit the potentiality of seaweeds as food, feed and fodder. As such the desirability of brown seaweed as animal feed mainly depends upon the level of phenolic compounds (Ragan and Jensen, 1978; Rao and Untawale, 1991).

The data presented in Table-8 is in conformity with the findings of above workers. However, it is necessary to add here that the bulk of the polyphenols are not readily accessible as reserve components, and indicate that modifications may be needed in the chemical defence and waste product hypotheses concerning the significance of algal polyphenols in general, and brown algal polyphenols in particular.

H) PROLINE

It is now well established that the proline is a stress product synthesized in response to drought and said to be osmotic substance (especially cytoplasmic osmoticum) during water stress (Boggess _et al_., 1976). Its accumulation under different types of stress such as salt (Cavalieri and Huang, 1979), tmperature stress (Chu _et al_., 1974), moisture stress (Singh and Singh, 1988) and pesdticide stress (Deshpande and Swamy, 1987) have been reported in plants. Mohanty and Sridhar (1982) stated that disease stress (biotic stress) may have the same effect and it may duplicate the abiotic stress such as drought, salt and temperature.

Since marine algae constantly receive salt water, it is thought worthwhile to study the proline level in different marine algae. It is evident from Table-9 that the chlorophycean and phaeophycean members exhibit higher concentration of proline content as compared to rhodophycean one. They have also exhibited a seasonal variation in proline level. Almost all the members have shown increase in proline content during summer months, while no significant change was noticed during winter season. The higher level of proline observed during summer months

Table - 9 : Seasonal variation in Proline content of different marine algae

Algae	Proline μ mole g^{-1} dry wt.		
	Post monsoon	Winter	Summer
Chlorophycophyta			
<u>Ulva fasciata</u>	12.1	12.0	15.2
<u>Chaetomorpha media</u>	9.1	9.4	12.3
Phaeophycophyta			
<u>Dictyota dichotoma</u>	8.31	8.12	10.4
<u>Padina tetrastromatica</u>	11.0	10.9	14.6
<u>Sphacelaria furcigera</u>	7.96	7.6	11.2
Rhodophycophyta			
<u>Ceramium rubrum</u>	4.84	4.63	8.3
<u>Hypnea valentiae</u>	5.88	5.2	9.8

can be attributed to the increase in the salinity level of seawater, and perhaps the increased proline level in the algal tissues help in maintaining the internal osmoticum of algal cell. This needs further investigation as to comment on the role of proline in marine algae, which is in progress.

I) CARBON ; HYDROGEN ; NITROGEN AND PHOSPHORUS

A unifying concept in biological oceonography is commonly expressed in terms of the "Redfield" ratio. As widely discussed (e.g. Redfield *et al*. 1963), the average carbon : nitrogen : phosphorus (C:N:P) atomic ratio of organisms in the sea is 106 : 16 : 1. This ratio is based on extensive analysis of marine plankton. A corollary to this standard compositional ratio of marine organisms is the observation that the net uptake and release of nutrients through biochemical processes in the sea also tend toward this same ratio. The concentration of macronutrients in seawater is non-conservative. Various nutrients absorbed by the seaweeds are replenished incessantely into ambient medium through trophic levels of various orders and/or directly by their death and decay. Consequently there is no death of these constituents for the perpetuation of plant life in the marine environment. Therefore, a comprehensive evaluation of nutrient levels in seawater and seaweeds is indispensible in the chemical oceanographic studies. Hence in the present investigation an attmpt has been made to study C, H, N and P content from different marine algae. The data is incorporated in Table-10.

The high C content was observed in a red algae *Ceramium rubrum* followed by a brown alga *Dictyota dichotoma*. The other seaweeds namely *Chaetomorpha media*, *Sphacelaria furcigera* and *Hypnea valentiae* exhibited more or less the same C content. The least is being observed in *Ulva fasciata* and *Padina tetrastromatica*. As regards H content the highest value is being observed in *C. rubrum* followed by *D. dichotoma*, *U. fasciata*, *H. valentiae*, *S. furcigera*, *P. tetrastromatica* and *C. media*.

The highest N content was noticed in red algae followed by green algae and brown algae with least in *S. furcigera*. The P level of *U. fasciata*, *C. media*, *D. dichotoma* and *H. valentiae* was more or less the same, while *P. tetrstramatica*, *S. furcigera* and *C. rubrum* exhibited low level of P. Generally the data of these macronutrients is expressed as C:N and N:P ratio and hence the same is also given in Table-10.

In phytoplankton C:N:P ratios (106:16:1) closely relate to seawater composition (Redfield *et al.*, 1963) but in seaweeds these values deviate. This may be due to presence of highly organized tissues in their body system. It may also be a

Table - 10 : C, H, N, and P content of different marine algae

Algae	Carbon %	Hydrogen %	Nitrogen %	Phosphorus %	C:N	N:P
Chlorophycophyta						
Ulva fasciata	19.86	5.50	2.16	0.112	9.19	19.28
Chaetomorpha media	23.14	4.40	1.03	0.119	22.46	8.65
Phaeophycophyta						
Dictyota dichotoma	29.37	5.56	1.85	0.106	15.87	17.45
Padina tetrastromatica	20.78	4.58	1.54	0.094	13.49	16.38
Sphacelaria furcigera	24.87	4.88	0.88	0.094	28.26	8.85
Rhodophycophyta						
Ceramium rubrum	30.38	6.14	2.98	0.062	10.19	48.06
Hypnea valentiae	23.56	4.90	2.35	0.137	10.00	17.15

physiological adaptation to meet the constraints caused by their amphibiotic intertidal habitat. Different groups of algae exhibit different C:N ratios. In nature, green, brown and red seaweeds occupy different positions in intertidal regions. Therefore, C:N ratio may differ accordingly (Rao and Indusekhar, 1989).

The metabolic changes caused in the life cycles of seaweeds also bring drastic changes in their C:N and N:P ratios. Similarly these ratios vary with phenology of seaweeds (Lapointe, 1987; Atkinson and Smith, 1983). Rao and Indusekhar, 1989 studied C:N:P of brown seaweeds and reported that high C:N ratios were due to senescence and slow growth and the variation in ratio is attributed to their different phenological stages. The normal values of N:P atomic ratios for seaweeds are reported to be around at 10:35 (Atkinson and Smith, 1983; Rao and Indusekhar, 1987). The values of C:N and N:P of the present investigation are well within the range. Thus tissue analysis of C, H, N and P can be used as standard measure of determining the nutritional status of algae. The tissue content of N or P may continue to increase far above the critical level when it is in abundant supply, but the excess has little effect on growth. Thus the critical, internal value for N is taken as the value of seaweed tissue concentration of N at the optimal growth of seaweed.

Rao and Indusekhar (1989) have reported C:N and N:P ratio with phenological stages of seaweed growth. Neighbors and

Horn (1991) have also studied C and N content of different marine algae. The values reported by them for C of green algae (26.1%), brown algae (23.8 to 35.9%) and red algae (16.4 to 34%) and N of green algae (3.1%), brown algae (1.7 to 1.8%) and red alga (1.0 to 4.0%) are in agreement with the values reported here. However, the data reported in Table 10 was analysed only for post-monsoon season. Since C:N and N:P ratios vary with phenology of seaweed, integrated values of the C:N:P of their life period would give better picture of the seaweed biomass.

J) SEASONAL VARIATION IN INORGANIC CONSTITUENTS

Composition of seawater changes from place to place and from month to month due to influence of various factors such as light, temperature, rainfall and biological activities (Joshi and Gowda, 1975). As a result, the chemical constituents of marine algae which grow in the ambient medium of seawater also vary. There is a good evidence that the inorganic elements (in addition to the organic elements C, H and O) are required by one or more algal species : N, P, K, Mg, Ca, S, Fe, Cu, Mn, Zn, Mo, Na, Co, V, Si, Cl, B and I. Of these, N, P, Mg, Fe, Cu, Mn, Zn and Mo are considered to be required by all algae and not replacable even in part by other elements (O'Kelley, 1974). In order to study this many investigators have analysed marine algae for the seasonal variations in inorganic constituents (Joshi and Gowda, 1975;

Agadi *et al*., 1981 and Kulkarni and Nimbalkar, 1981).

The marine algal species also have been suggested to be the indicators of pollution (Bryan and Hummerstone, 1973; Fuge and James, 1974; Zingde *et al*., 1976 and Seeliger and Edwards, 1977). In present investigation therefore, an attempt has been made to study the seasonal variation in different marine algal species of Malvan coast. The data is expressed in ppm and g 100^{-1} dry weight in Table-11 and 12. However, seasonal variation in mineral contents is expressed in Meq 100^{-1}g. dry weight (Table-13) and the same is used for the discussion purpose.

All the inorganic constituents showed distinct seasonal variations. Higher concentration of Na, Ca,k Mn, Cu, Cd, Cr, Pb and Ni were recorded in the early summer season while K and Zn in post monsoon season and Mg and Fe during winter season. These variations may be due to the environment to which they are exposed. Another possible reason for this variation may be the stress received by the seaweeds as a result of the fluctuations in temperature, salinity or turbidity (Seeliger and Edwards, 1977).

Among the various algae studied, *H. valantiae* showed higher concentration of Na followed by *C. media*. Marine algae, generally maintain a low level of Na even though its concentration in seawater is found more than any other cations.

Table 11 : Inorganic constituents of different marine algae analysed during post monsoon season

Algae	Na	K	Ca	Mn	Mg	Fe	Zn	Cu	Cd	Cr	Pb	Ni
Chlorophycophyta												
Ulva	170	338	146	0.74	654	12.0	0.37	0.09	0.08	0.13	0.57	0.15
Chaetomorpha	300	438	138	0.62	110	28.0	0.30	0.09	0.15	0.27	0.50	0.18
Phaeophycophyta												
Dictyota	200	157	1403	7.0	199	123	0.66	0.24	0.13	0.65	0.89	0.41
Padina	200	300	561	7.0	698	89	0.70	0.18	0.11	0.56	0.65	0.30
Sphacelaria	230	71	228	10	153	217	1.68	0.43	0.10	0.95	0.74	0.60
Rhodophycophyta												
Ceramium	220	126	146	4.0	81.6	66	0.70	0.23	0.09	0.58	0.66	0.21
Hypnea	740	224	300	4.0	117	95	0.49	0.19	0.09	0.55	0.68	0.25

Values are expressed in ppm and are mean of three determinations.

Table 12 : Inorganic constituents of different marine algae analysed during post monsoon season

Algae	Na	K	Ca	Mn	Mg	Fe	Zn	Cu	Cd	Cr	Pb	Ni
Chlorophycophyta												
<u>Ulva</u>	1.7	3.38	1.46	0.007	6.54	0.12	0.004	0.001	0.008	0.001	0.006	0.002
<u>Chaetomorpha</u>	3.0	4.38	1.38	0.008	1.10	0.28	0.003	0.001	0.002	0.003	0.005	0.002
Phaeophycophyta												
<u>Dictyota</u>	2.0	1.57	14.03	0.07	1.99	1.23	0.007	0.002	0.0014	0.007	0.009	0.0041
<u>Padina</u>	2.0	3.0	5.61	0.07	6.98	0.89	0.007	0.0018	0.001	0.006	0.007	0.003
<u>Sphacelaria</u>	2.3	0.71	2.28	0.10	1.53	2.17	0.017	0.0043	0.001	0.0095	0.0074	0.006
Rhodophycophyta												
<u>Ceramium</u>	2.2	1.26	1.46	0.04	0.81	0.66	0.007	0.0023	0.0009	0.0058	0.0066	0.0021
<u>Hypnea</u>	7.4	2.24	3.0	0.04	1.17	0.95	0.0049	0.0019	0.00087	0.005	0.006	0.0025

Values are expressed in g 100 g dry tissue and are mean of three determinations.

Table 13 : Seasonal variations in inorganic constituents of different marine algae

Algae	Season	Na	K	Ca	Mn	Mg	Fe	Zn	Cu	Cd	Cr	Pb	Ni
Ulva	PM	73.94	86.44	72.8	0.25	573.82	6.44	0.12	0.015	0.014	0.057	0.75	0.068
	W	70.80	82.3	68.3	0.18	596.3	9.2	0.10	0.019	0.018	0.060	0.78	0.072
	S	74.82	84.53	74.54	0.28	540.3	7.43	0.10	0.026	0.023	0.065	0.8	0.075
Chaetomorpha	PM	130.48	112.02	67.86	0.22	90.4	15.04	0.09	0.015	0.035	0.017	0.62	0.068
	W	125.34	106.30	61.64	0.18	98.92	18.23	0.06	0.018	0.046	0.018	0.68	0.069
	S	132.9	108.9	69.5	0.29	86.3	17.6	0.08	0.02	0.048	0.021	0.73	0.072
Dictyota	PM	86.99	40.15	700.09	2.55	163.65	66.06	0.21	0.037	0.025	0.4	1.12	0.14
	W	84.56	35.3	690.2	2.3	180.3	69.03	0.16	0.039	0.028	0.42	1.18	0.16
	S	87.3	38.2	696.8	2.6	154.9	67.2	0.18	0.043	0.032	0.45	1.23	0.17
Padina	PM	86.99	76.72	279.9	2.55	574.1	47.81	0.21	0.028	0.017	0.35	0.87	0.10
	W	85.3	72.3	264.3	2.45	593.2	50.43	0.14	0.036	0.018	0.38	0.89	0.13
	S	88.43	73.9	290.6	2.7	562.4	49.3	0.19	0.045	0.019	0.42	0.94	0.18
Sphacelaria	PM	100.03	18.15	113.7	3.64	125.8	116.5	0.52	0.067	0.002	0.55	0.92	0.20
	W	96.42	15.3	108.3	3.45	146.3	123.8	0.36	0.073	0.002	0.63	0.93	0.25
	S	102.9	17.6	121.6	3.71	118.5	119.3	0.46	0.075	0.004	0.62	0.98	0.29
Ceramium	PM	95.68	32.2	72.85	1.46	66.6	35.45	0.21	0.036	0.016	0.33	0.082	0.071
	W	93.34	30.45	67.6	1.32	74.5	39.6	0.14	0.039	0.019	0.38	0.86	0.083
	S	97.45	31.6	79.2	1.63	60.8	36.4	0.16	0.042	0.023	0.43	0.89	0.085
Hypnea	PM	321.8	57.2	149.7	1.46	96.2	51.02	0.15	0.03	0.015	0.32	0.85	0.085
	W	304.5	51.3	138.6	1.36	99.4	56.4	0.11	0.032	0.019	0.36	0.86	0.088
	S	332.4	55.63	156.4	1.58	90.3	53.4	0.14	0.038	0.024	0.38	0.89	0.093

Values are expressed in meg 100 g dry wt.
PM = Post monsoon, W = Winter, S - Summer

The Na content of various marine algae reveal that its concentration varie~~s~~d from species to species (Rao *et al.*, 1983). However the importance of Na for marine algae is not clearly understood. It seems, like that of K, sodium has a specific role in metabolism in plants growing under saline environment.

Potassium is one of the most essential elements for the plant growth. It showed highest concentration in *C. media* and least in *S. furcigera*.

It has been accepted that algae also require calcium, atleast in the absence of strontium (O'Kelley, 1974). The quantity required, however, appears to vary greatly between species. The data reported in Table-13 clearly indicates that variation in Calcium concentration, the highest being observed in brown algae *D. dichotoma*, *P. tetrastromatica* and *S. furcigera* followed by red alga *H. valentiae*. However the Ca requirement of *Ceramium rubrum*, and green algae *C. media* and *U. fasciat~~e~~a* appears to be low.

Since nearly all algae possess chlorophyll and all are expected to carry out molecular phosphate transfers, Mg is without doubt needed universly by algal species. The highest Mg value exhibited by *U. fasciata* and *P. tetrastromatica* (Table-13) can be correlated very well with high chlorophyll content (Table-4).

The Mn and Fe content also showed large variation with respect to species. The higher concentration of both these elements was found in brown algae as compared with green and red algae.

The earliest demonstration of Zn requirement in algae was in *Stichococcus bacillaris* (Eilers, 1926). Much of the interest in Zn and algae is related to uptake mechanisms. Zinc accumulation factors upto 1200 had been reported for marine algae however, it had also been noted that killed as well as living cells accumulate Zn and Zn can be removed rapidly from some algal cells after having been accumulated (O'Kelley, 1968).

Copper requirement of algae, mainly involved in photosynthesis for plastocyanin, has been reported in *Chlorella ellipsoidea* (Katoh *et al*., 1961).

The concentration of Zn and Cu reported in Table-13 is comparatively higher in brown algae.

The heavy metals such as Cd, Cr, lead and nickel detected in all the algae of present investigation lead us to surmise that heavy metal pollution is taking place. However, to arrive at concrete conclusion, further investigation of the analysis of seawater as well as seaweeds is essential.

Seaweeds are well known for their ability to accumulate trace elements. Moreover, this bioaccumulation is magnified to several thousand times, with respect to their concentrations in seawater. Further, it is necessary to add here that the trace metal concentrations in the seaweeds are not subject to short term erratic fluctuations, but intigrate the concentration of metals in seawater over relatively long periods of time, making them valuable tool for monitoring harmful trace metals in seawater (Perstone et al., 1972). Since the algae has an importance as primary producers in coastal water, their implication as metal concentrating agent cannot be under estimated.

Thus heavy metal accumulation in the seaweeds of Malvan has posed a lerking danger, though in no way is alarming at present, demands to probe into the problem in future.

K) AMINO ACID COMPOSITION

Amino acid composition studied in different marine algae is given in Table-14. To support the data, the tracing[illegible] of chromatograph is given in Fig. 4 and 5. Ascending paper chromatography of different marine algae for amino acid showed the presence of aminoacids *viz* glycine + serine, aspartate, threonine, tyrosine, methionine and valine with varying concentration. Glycine and serine concentration (high) was more or less same in U. fasciata, C. media, P. tetrastromatica, D. dichotoma and C.

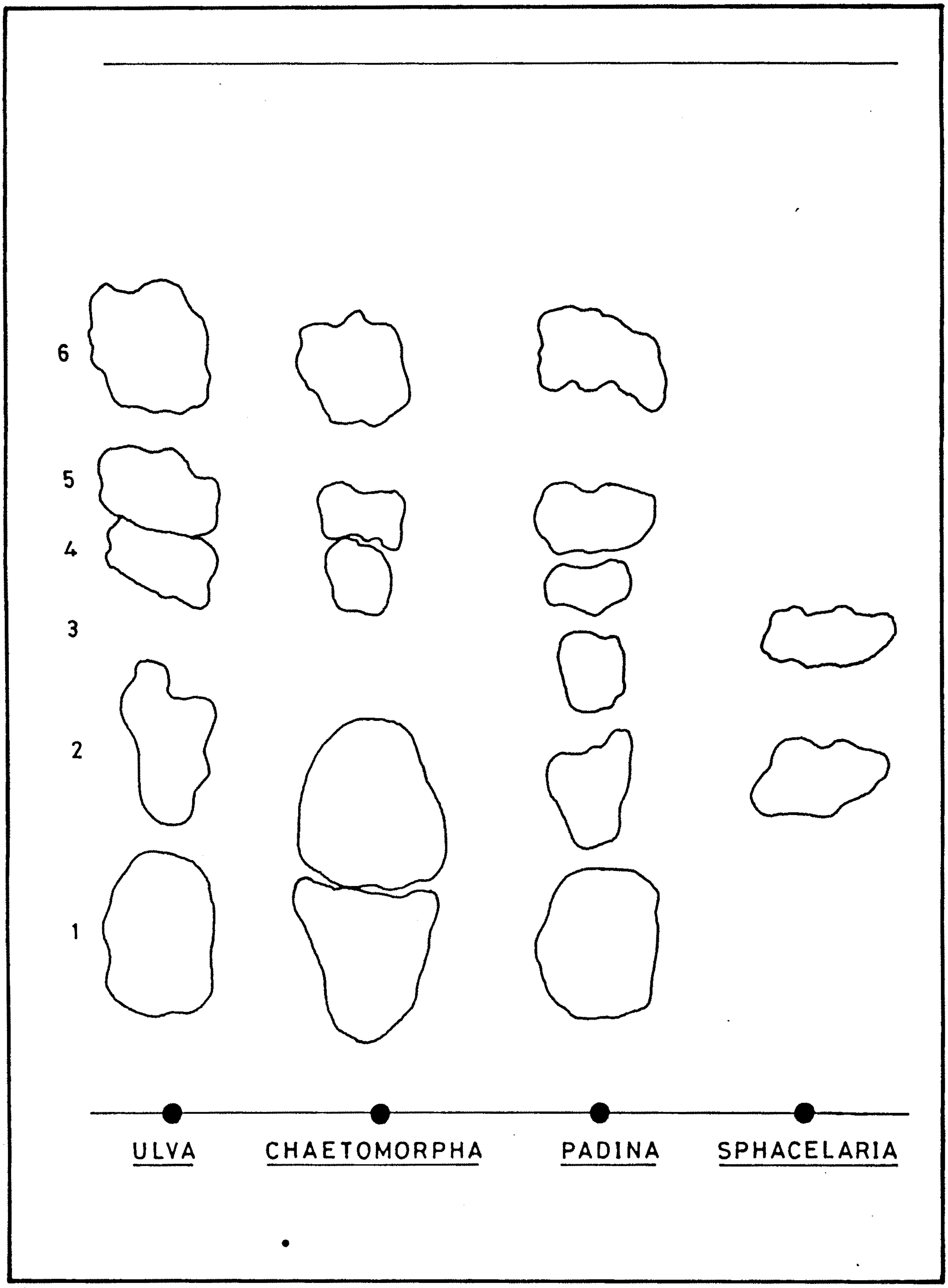


FIG. 4

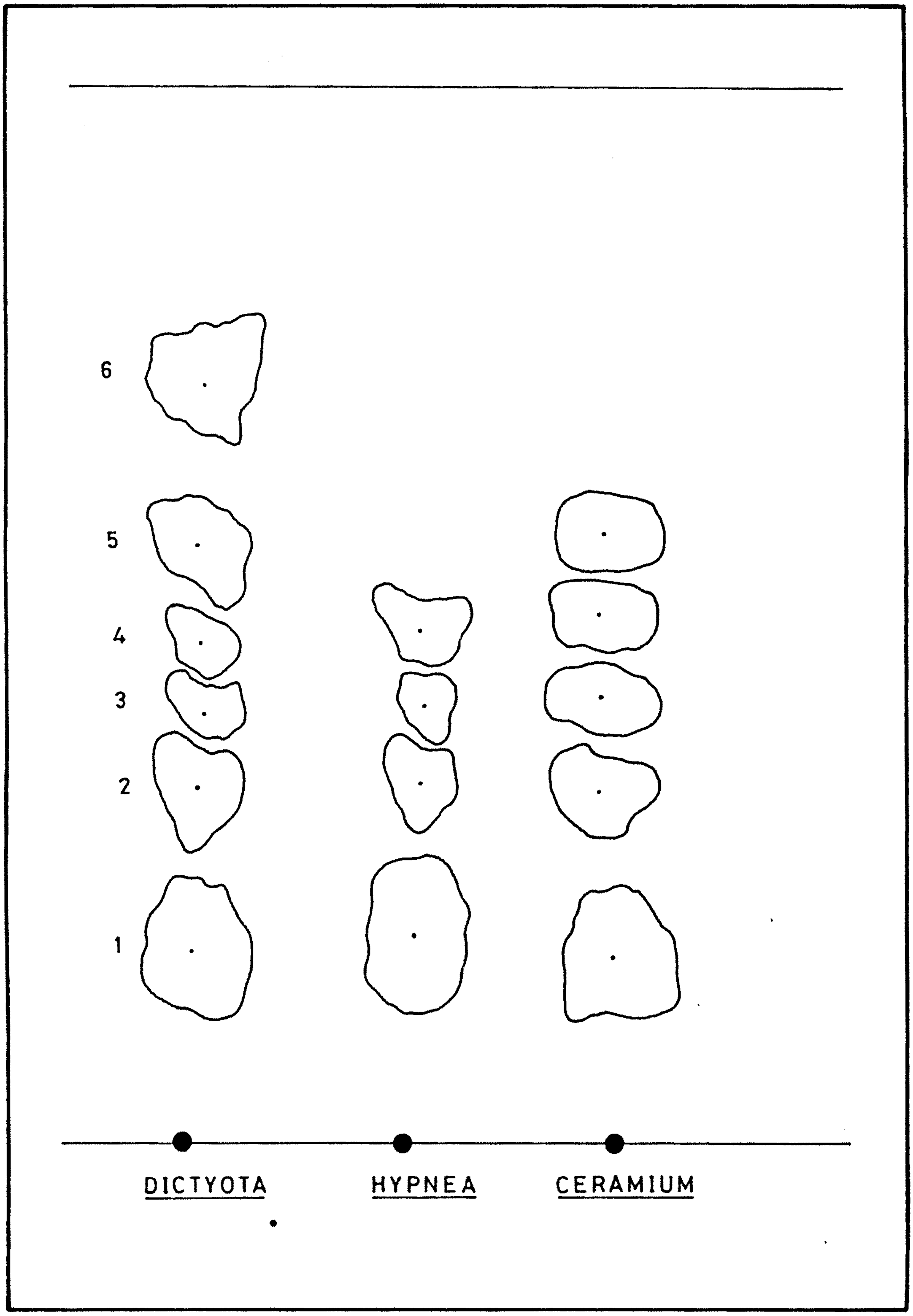


FIG. 5

Table - 14 : Amino acid competition of different marine algae separated by ascending paper chromatographic technique.

Spot No.	Amino acids	*Ulva fasciata*	*Chaetomorpha media*	*Padina tetrastromatica*	*Sphacelaria furcigera*	*Hypnea valentiae*	*Dictyota dichotoma*	*Cramium rubrum*
1.	Glycine + Serine	++++	++++	++++	-	+++	++++	++++
2.	Aspartate	+++	+++++	++	++	++	+++	+++++
3.	Threonine	trace	trace	trace	trace	+	+	++
4.	Tyrosine	++	+	trace	-	++	++	++
5.	Methionine	+++	++	+	-	-	++	++
6.	Valine	+++	++	+	-	-	++	-

rubrum, whereas *H. valentiae* has a moderate and not detected in *S. furcigera*. As regards aspartate, very high concentration was observed in *C. media* and *C. rubrun*., moderate in *U. fasciata* and *D. dichotoma*, medium in *P. tetrastromatica*, *S. furcigora* and *H. valentiae*. A trace amount of threonine was noticed in *Ulva*, *Chaeomorpha*, *Padina* and *Sphacelaria* while medium in *Ceramium* and low in *Hypnea* and *Dictyota*. Tyrosine was not detected in *Sphacelaria*, however its medium concentration was found in *Hyprea*, *Dictyota*, *Ceramium* & *ulva*, low in *Chaetomorpha* and trace in case of *Padina*. Methionine and Valine were not detected in *Sphacelaria* and *Hypnea* but the moderate concentration was observed in *Ulva*, medium in *Chaetomorpha* and *Dictyota*.

Thus it is very clear from the observations that, the amino acid composition varies with species. The further details regarding the quantification of amino acids, organic acids and sugars using radio tracer techniques will throw more light. As such Patil and Joshi (1970); Joshi and Karekar (1973); Shitole (1980); Kulkarni (1984) have studied the amino acid, organic acid and sugar composition as a product of the photosynthesis using radio tracer technique in *Ulva lactuca*, *Enteromorpha tubulosa*, *Caulerpa racemosa* var. *Peltata* and *Gracilaria corticata* respectively. In order to get the clear cut idea about the dietary aspects of the seaweeds, and to establish the harvest time accordingly it is necessary to investigate the above aspects with respect to season and growth of seaweed.

L) PHENOLIC COMPOUNDS

The phenolic compounds separated from different marine algae employing ascending paper chromatographic technique have been depicted in Table-15, and tracing of the same is given in Fig.6 and 7. It is clear from the Fig. 6 & 7 that *Sphacelaria* exhibited maximum number of phenolic compounds namely Proanthocyanodines, coumaric acid, querecetin derivatives, myricetin, tannic acid, catechol and caffeic acid. However, *Chaetomorpha* exhibited only two phenolic compounds namely quercetin and myricetin. The phenolic compounds namely Caffeic acid and quercetin were found in all the algae of present investigation, except *Chaetomorpha*. Catechin was found only in *Padina*. Coumaric acid was predominant in *Ceramium* and *Sphacelaria*. Catechol in *Dictyota* and Tannic acid made its appearnce in all algae except *Ulva*, *Cha~~t~~etomorpha* and *Padina*.

In natural seawater algae seem to be supplied with phenolic substances (Fries, 1972). Sieburth and Jensen (1969) reported presence of small fractions of phenols in seawater collected from the *Fucus*-*Ascophyllum* zone. Further they have reported that the phenolic compounds help to increase the growth of *Goniotrichum*, a brown seaweed. Provasoli and Pintner (1968) have found that several phenolic compounds influence the

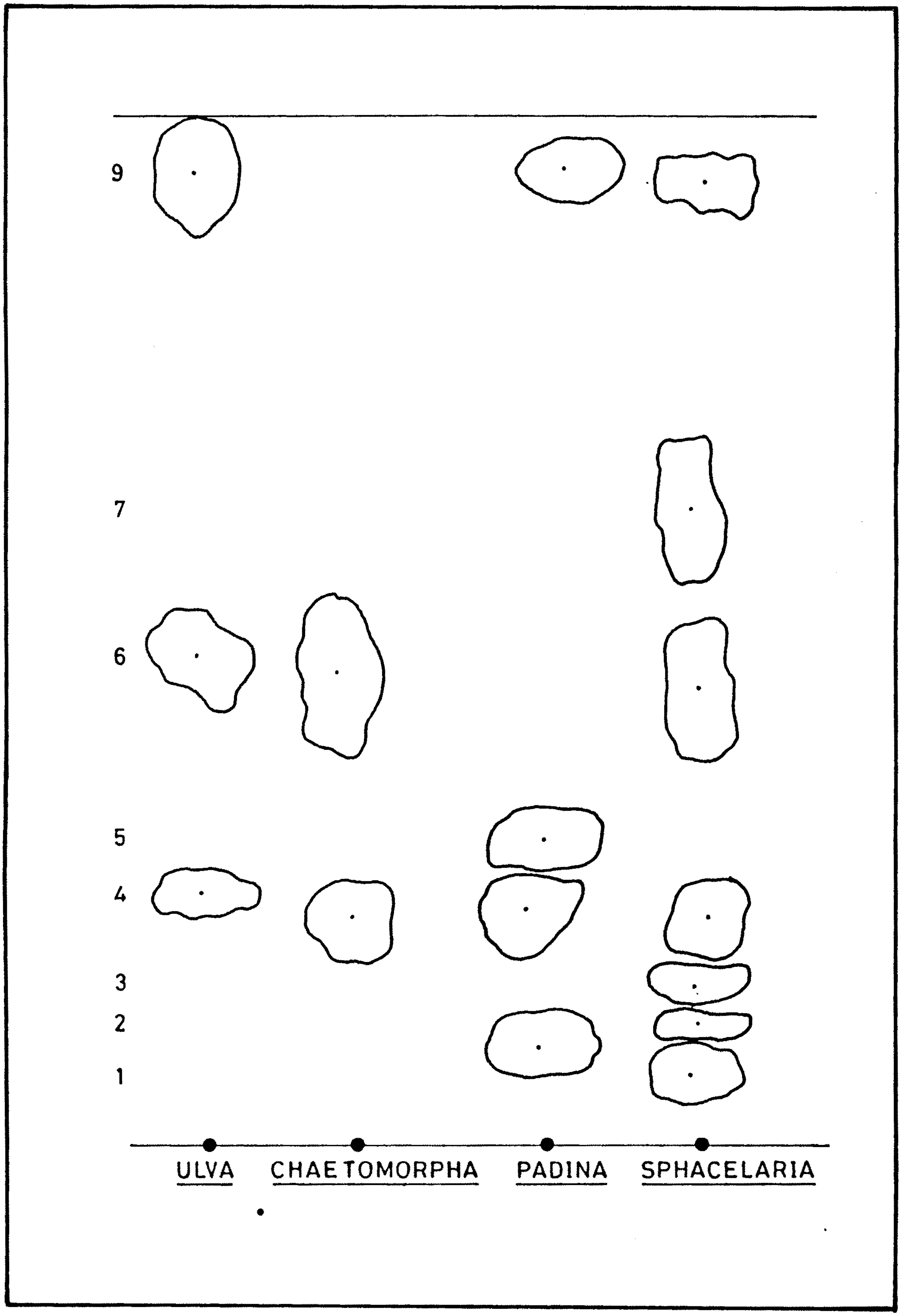


FIG. 6

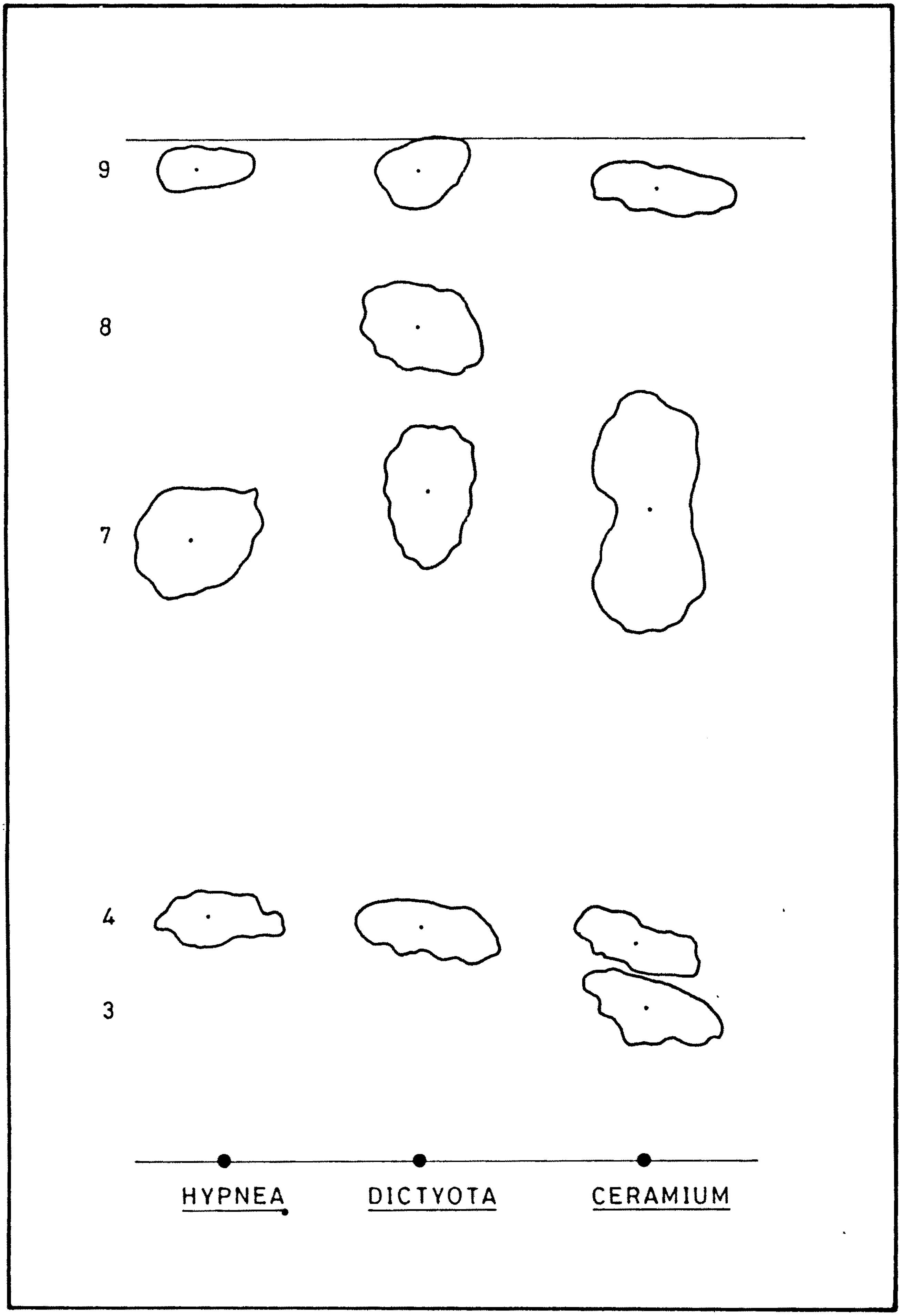


FIG. 7

Table - 15 : Detection of phenolic compounds from different marine algae using ascending paper chromatography.

•Spot No.	Colour under UV	Colour under UV+NH_3	0.3% $K_3Fe(CN)_6$ + $FeCl_3$ (1:1 mixture)	Rfx100 in BAW	Probable identification
1	–	–	Blue	7.9	Proanthocyanodins
2	–	–	Faint blue	13.0	– ,, –
3	Greenish yellow	Greenish yellow	Faint blue	17.0	Coumaric acid
4	Violet	Yellow	Blue	24.0	Quercetin derivative
5	Violet	Violet	–	31.0	Catechin
6	–	–	Blue	46.0	Myrecetin
7	–	–	Blue	63.0	Tannic acid
8	–	–	Blue	82.0	Catechol
9	Violet	Yellow	Blue	96.0	Caffeic acid

morephology of *Ulva*, ferulic acid is one of them.

This clearly indicates that phenols are essential to algal growth in small concentration and these compounds are largely confined to the most of the brown seaweeds (Table 8, 15 and Fig. 6 and 7). However, to establish the role of phenols in marine algae, it is essential to quantify the phenolic compounds with respect to season and age of the seaweeds.

M) ALGINIC ACID, MANNITOL AND AGAR-AGAR

It is well established that the brown seaweeds are rich in alginic acid and mannitol and red seaweeds in agar-agar content. In order to know the level of these biochemicals, different marine algae have been analysed and the data is depicted in Table 16. Along with brown algae viz., *Dictyota*, *Padina* and *Sphacelaria* the green algae *Ulva*, *Chaetomorpha* and red algae *Ceramium* and *Hypnea* were analysed for alginate content. It is vividly clear from the Table 16 that the brown seaweeds are rich in alginic acid. Among the brown seaweeds, *Dictyota* exhibited highest concentration than *Padina* and *Sphacelaria*. The richness of alginate content can be judged very well from the fibrous precipitate of alginate (Plate 13). The amorphous precipitate. clearly indicates that *Ulva*, *Hypnea* and *Ceramium* do not contain alginic acid.

Plate - 13

Fibrous Precipitation of alginic acid

Table - 16 : Alginic acid, mannitol and Agar-agar content from different marine algae.

Algae	Alginic acid %	Manitol %	Agar-agar %
Chlorophycophyta			
Ulva fasciata	-	-	-
Chaetomorpha media	-	-	-
Phaeophycophyta			
Dictyota dichotoma	26.65	4.5	
Padina tetrastromatica	13.0	3.1	
Sphacelaria furcigera	10.5	2.85	
Rhodophycophyta			
Ceramium rubrum	-	-	34.25
Hypnea valentiae	-	-	57.2

The mannitol content studied in brown seaweeds varied from 2.85 to 4.5%, the highest being in Dictyota followed by Padina and Sphacelaria.

The agar-agar content was found more in Hypnea than that of Ceramium. This difference in agar level can be attributed to the thallus structure of the respective algae. The data given in Table 16 is in agreement with the values reported elsewhere (Mehta and Parekh, 1978; Onraet and Robertson, 1987; Kalimuthu *et al*. 1987; Kalimuthu, 1989). However, to get the complete idea about the potential sources for these biochemicals, a comprehensive work with respect to seawater, season and age of the seaweed is necessary. The present attempt is just a beginning in this direction.