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AN ECOLOGICAL STUDY ON FRESHWATER ALGAL MATS*

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Abstract

The paper deals with the ecology of freshwater mat-forming algal communities around Hyderabad, India. Primary production and surface spreading capacities of these mats were also studied. The most common mat-forming algae in the waters surveyed were ***Cladophora, Spirogyra*** and ***Rhizoclonium.*** However, their sociability was less than that of ***Oedogonium, Zygnema*** and ***Oscillatoria. Spirogyra*** had a strong tendency to form unialgal mat whereas most of the other forms were bialgal and very rarely polyalgal. The fall in the ambient temperature resulted in the sudden disappearance of ***Rhizoclonium*** and ***Spirogyra. Cladophora*** and ***Hydrodictryon*** were found to be more sensitive to the changes in pH, CO_3^{--} and HCO_3^-. The results also indicated that there was a strong negative correlation between the "surface spread" and mineral content of filamentous algae. It was also noticed that algae with a great capacity to spread horizontally contained more pigments and hence were more efficient photosynthesizers. The highest production rate (27.5 mg C/ml/day) was recorded for ***Spirogyra,*** while ***Rhizoclonium*** showed the lowest production rate of about 6.8 mg C/ml/day.

Introduction

Most of the freshwater studies the world over are directed towards the ecology of plankton, periphyton, benthos and macrophytes with little mention whatsoever of algal mats. For the ubiqnitous nature of their distribution, they did attract the attention of classical limnologists but their approach towards mat ecology was casual rather than serious. As far as the author knows, the only serious efforts in this direction are those of Herbst (1969), Whitton (1970) and Hillebrand (1977). Biomass studies have been attempted by Moss (1968) and O_2-production efficiencies by Pieczynska (1965). The paucity of information on the ecology of algal mats in general and of

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Indian waters in particular was thus instrumental in including it in the present study. The paper deals with the distribution, sociability, periodicity, surface spread, biomass and production studies.

Materials and Methods

Sampling sites

Algal mats were investigated in two permanent lakes—Husain Sagar and Saroornagar—and several temporary ponds lying in the vicinity of Hyderabad. In case of Husain Sagar, observations were spread over a period of two years while Saroornagar was under observation only for one. The temporary ponds were studied for a month or two depending upon the persistence of the mats in them.

Sampling method

The lumps were sampled with the help of a plastic strainer and forceps and were washed with the lake water to clean the entangled detritus and silt. The adherent water was blotted out by mildly pressing them between the sheets of blotting paper. A known volume (15 ml) of the blotted algae was measured out by volume displacement. The sample was further fractioned similarly for estimation of community structure, surface spread, biomass and pigments.

Methodology of analysis

(1) Chemical and physical analyses

Colour	Welch (1948)	Glass-disk method with U. S. Geological Survey outfit.
Turbidity	—do—	With U. S. Geological Survey Turbidity Rod.
pH		Lovibond comparator.
CO_3^{--}	Wilcox and Hatcher (1950)	Using phenolphthalein indicator.
HCO_3^-	—do—	Using Methyl orange indicator.
Cl^-	Wilcox and Hatcher (*op. cit.*)	Using Potassium chromate indicator.
Dissolved O_2	APHA (1971)	Wingler Method with Alsterberg (Azide) modification.
Oxidizable organic matter	Thresh, Beale and Suckling (1930)	Estimatons were made on 100 ml sample incubated for 4 hours at 40°C.
NH_3	APHA (*op. cit.*)	Distillate was collected in 0.05 N H_2SO_4 which was back titrated with 0.05 N NaOH using Bromcresol green indicator.
Alb. NH_3	APHA (*op. cit.*)	Strongly alkalined after removal of NH_3; distillation and titration as for NH_3.

NO_2^-	APHA (*op. cit.*)	Colour compared in Nessler cylinders.
NO_3^-	Wilcox and Hatcher (*op. cit.*)	Phenoldisulphonic acid Method—KNO_3 Soln. was used as primary standard and comparisons were made in Nessler cylinders.
PO_4^{---}	Golterman and Clymo (1969)	Ascorbic Acid Method—absorance was measured at 680 nm using Spectronic 2(spectrophotometer.
SO_4^{--}	Golterman an Clymo (*op. cit.*)	Turbidimetric, absorbance was measured at 420 nm in Spectronic 20 spectrophotometer.
Total, Dissolved and suspended solids	APHA (*op. cit.*)	Residue was not ignited. It was dried at 105°C for one hour.
Total, Dissolved and particulate Fe	APHA (1947)	Thiocyanate Method, colour comparison in Nessler cylinders.

(2) Biological analysis

i. Community structure: It was determined by spreading the mat on five microscope slides and counting the number of individuals of each species under low power. Thus it was possible to designate a particular species as 'abundant', 'common' or 'rare' depending upon a predecided number of its occurrence. It was not advisable to represent them numerically since the same filament occurs again and again, and gives a false impression if represented numerically. Another difficulty encountered was the lack of fruiting bodies in the forms collected. Their identification was therefore restricted only up to genus.

ii. Surface spread: Four identical glass-bottomed trays made specifically for this purpose were half filled with pond water from where the mats were collected. Mat samples each measuring exactly 1 ml were introduced in the trays. The trays were then covered with glass-lids and kept aside for 24 hours in a quiet place well protected against wind disturbance and undue vibrations. The algal mass was thus allowed to attain its natural spread. After 24 hours a graph paper was inserted under the glass bottom of the trays. The number of squares covered by the mat was counted, which on conversion in mm^2 gave an approximate spreading capacity of the mat concerned.

iii. Biomass: Air-dry weight (fresh weight) was determined on a 10 ml fraction of the blotted out sample. The water was further allowed to drain off by placing the sample in a funnel to which a previously weighed Whatman '42' filter paper was fixed. The material was kept in air to dry and turned frequently till the water ceased to drip and algae just began to shrivel. Depending on air temperature and humidity the time required for this process varied from 30 minutes to 12 hours. It was then weighed to determine the air-dry weight.

The air-dried sample was further utilised to determine the oven-dry weight and loss on ignition. To estimate the former, filter paper was dried at 104°C for one hour. It was weighed after cooling to room temperature. The difference in weight gave the oven-dry weight. The ovendried filter was incinerated in a muffle furnace at 800°C for four hours and the ash content determined. The difference in the oven-dry weight and the residual ash gave 'loss on ignition'.

Pigments were extracted from 1 ml of freshly collected and blotted out algae that was grinded in porcelain mortar with 50 ml of 90% acetone. The extract was kept in dark for 24 hours and the different components of pigments were measured spectro-photometrically after centrifuging the extract.

iv. Gas exchage experiments: About a litre of lake water was passed through a frittered porcelain candle filtration unit (used normally for domestic purposes). This was done primarily to eliminate phytoplankton and zooplankton but it might have eliminated a good percentage of bacteria as well. Three bottles of 300 ml capacity were filled with filtered water, one of which was covered with tinfoil. One ml of algal mat was introduced in each of them and initial O_2 was determined in one of the uncovered bottles. The remaining two were then immersed in the lake at identical conditions of temperature and light and oxygen changes estimated after two hours of exposure. Another series of experiments was carried out for a period of two hours soon after the first experiment was over. The timing of the experiments was from 12 noon to 2 p.m. and from 3 to 5 p.m.

From the changes in oxygen concentrations in the covered and uncovered bottles gross and net primary production were computed as is normally done for phytoplankton. The values of four hour O_2 production were trebled to obtain a day-long (12 hours) production. O_2 values were converted to carbon values by multiplying them with a factor of 0.375 as suggested by Sreenivasan (1964). Thus the gross production in the following discussions represents the fixed carbon per unit volume of algal biomass per unit time (mg C/ml/day).

Results and Discussion

Distribution

The abundance of various filamentous genera varied greatly in different bodies of water studied. This has been shown in Table 1.

Oedogonium was never found to form independent mats and was mostly associated with *Spirogyra* (ponds 1 & 2) and rarely with *Rhizoclonium* (Saroorngar). It occurred in waters rich in NO_3^- (8.6–9.9 mg/l) and O_2

(8.0–10.0 mg/l). *Oedogonium* could tolerate salinity (dissolved solids) upto 1052–1064 mg/l with SO_4^{--} as high as 163–182 mg/l. Its requirement of phosphorus was probably very little as the waters which harboured it showed PO_4^{---} only in traces. It grew in waters with low oxidizable organic matter and moderate amount of Fe (0.1–0.15 mg/l) with Fe/C around 0.04.

Table 1. *Distribution of filamentous algae in waters around hyderabad*

Community	Permanent water bodies				Temporary water bodies										
	Husain sagar	Saroor nagar	Nadimi	Banjara	1	2	3	4	5	6	7	8	9	10	11
Oedogonium		+			+++	++									
Cladophora	++++	+++										++++			
Rhizoclonium	+	++++													+++
Pithophora							+	++++		+++					++
Hydrodictyon	+						+++								
Zygnema		+	++												
Spirogyra	+++	+		++++	++	+++	++		++++	+			++++	++++	+
Sirogonium			+++								++++				
Oscillatoria	+	+													+

++++ Pure
+++ Dominant
++ Sub-dominant
+ Common

Cladophora formed a unialgal mat in pond 8 and on certain occasions in Husain Sagar but was often associated with *Rhizoclonium, Spirogyra* and *Oedogonium* in Husain Sagar and Saroornagar. Apparently the alga and its associates were favoured by high turbidity of water (suspended solids 123–196 mg/l), with a colour range of 46–55 mg/l in filtered samples. The ponds of its occurrence also showed high HCO_3^- (265–371 mg/l), O_2 around 4.6–6.5 mg/l and total Fe in the range of 0.13–0.35 mg/l. The phosphorus requirement of the association was probably quite low (0.068 gm/l). *Cladophora* formed unialgal mats in waters with high dissolved organic matter (3.6–4.1 mg/l) and PO_4^{---} (0.4–0.6 mg/l). Tweed River Purification Board (1957) also noted the significance of PO_4^{---} in distribution of *Cladophora glomerata*. The occurrence of *Cladophora* is associated with pollution (Hawkes, 1964; Neil and Owen, 1964; Hutchinson, 1975). According to Patrick (1975) if the organic load is heavier, a decided shift from a diatom-dominated flora to one that has large populations of green algae such as *Oedogonium* and *Cladophora* occurred.

Rhizoclonium formed a unialgal mat in Saroornagar on certain occasions, and was associated with *Spirogyra, Pithophora* and *Cladophora* on others. These algas were also associated with it in Husain Sagar, and in pond 11.

All these waters waters weie turbid (63–85 mg/l), concentrated (dissolved solids, 1196–1266 mg/l) and alkaline (pH 7.4–9.0) and showed high HCO_3^- (371–414 mg/l), Cl^- (135–249 mg/l) and SO_4^{--} contents (157-355 mg/l). These waters were also rich in inorganic nitrogen (2.7–7.5 mg/l), particularly NH_3 (3–8 mg/l) and carbonaceous organic matter (3.9–5.3 mg/l). Probably it preferred NH_3 as a source of nitrogen and oxidizable organic materials as a source of carbon.

Pithophora appeared as a pure mat in one pone, in association with *Rhizoclonium*, *Spirogyra*, and *Oscillatoria* in another, and only with *Spirogyra* in two. It seemed to be a clean water form as the waters from which it was recorded were significantly devoid of turbidity (24 mg/l) and dilute (dissolved solids, 240–440 mg/l). They also contained little CO_3^{--} (17.0–28.5 mg/l), HCO_3^- (63–150 mg/l), Cl^- (17.3–39.8 mg/l), dissolved organic matter (2.5 mg/l), SO_4^{--} (38 mg/l) and PO_4^{---} (0.08–0.10 mg/l). These waters were characterised in having greater concentrations of NO_3^- (0.4–0.6 mg/l), total Fe (0.08–0.16 mg/l) and O_2 (9.0–10.0 mg/l).

Hydrodictyon which is a mesh of cells rather than a filament, formed a pure strand only once in Husain Sagar. It was often associated with *Cladophora* and *Spirogyra*. In a temporary pond it formed an association with *Spirogyra* and *Pithophora*. These waters were highly coloured (76–200 mg/l), alkaline (pH around 9.4) and polluted. They were rich in inorganic carbon (64 mg/l), NO_3^- (0.8–1.1 mg/l), NH_3 (0.9–3.6 mg/l) and PO_4^{---} (0.4–1.0 mg/l). It however was not recorded from waters with low oxygen content. Venkateswarlu (1976) put it under species favoured by low temperature, low organic matter and high dissolved oxygen.

Spirogyra had a strong tendency to form unialgal mats both in perennial and temporary waters. Even in Husain Sagar which had many filamentous algae, it was rarely recorded associating itself with *Oscillatoria*, *Cladophora* and *Rhizoclonium*. It was very sensitive towards pH, and occurred only in waters with that between 8.4–8.6 irrespective of the concentrations of CO_3^{--} and HCO_3^-. The waters which harboured its unialgal mats were distinctly rich in NO_3^- (0.3–0.5 mg/l) and PO_4^{---} (0.1–0.4 mg/l).

Sirogonium was recorded as a unialgal mat in a temporary pond. It occurred in association with *Zygnema* in a perennial lake. These waters exhibited low turbidity (63–85 mg/l), pH around 8.5, and NO_3^- around 0.5 mg/l. They were deviod devoid of $NO^-{}_2$, NH_3 and nitrogenous orgnic matter. They also contained carbonaceous organic matter in quite low concentration (1.97–2.8 mg/l). It may therefore be regarded as a clean water form avoiding polluted waters.

Zygnema was never recorded as a unialgal mat from these waters. It associated itself with *Spirogyra* in Saroornagar and with *Sirogonium* in Nadimi. The chemical peculiarities of waters discssed in case of *Sirogonium* were relevant in the ecology of this alga as well. Like *Sirogonium* this may also be classed under clean water forms.

Oscillatoria, though a common component of the planktonic community of the waters of this region, was never recorded as unialgal mat from any of them. Only once it occurred as a dominant form in one of the algal associations of Husain Sagar.

Sociability: It is evident from the above description that some of the filamentous algae had quite a strong tendency to form unialgal mats while others occurred in bialgal, trialgal or polyalgal associations. An attempt was therefore made to quantify their 'Sociability'—tendency to associate with other filamentous algae. This was calculated by the following self-devised formula;

$$\% \text{ Sociability} = \frac{\text{No. of situations in which the alga occurred in association}}{\text{Total number of situations in which the alga occurred}} \times 100$$

The results are presented in Table 2 in the increasing order of the percentage of Sociability.

Table 2. *Percentage "Sociability" of filamentous algae with the relavent data from which it was calculated*

Algae	Occured in	As unialgal mat	As bialgal mat	As trialgal mat	As polyalgal mat	Sociability %	Common associates
Oedogonium	4	Nil	3	1	Nil	100	*Rhizoclonium* *Spirogyra*
Zygnema	2	Nil	2	Nil	Nil	100	*Spirogyra* *Sirogonium*
Oscillatoria	5	Nil	4	Nil	1	100	*Rhizoclonium* *Spirogyra*
Rhizoclonium	32	3	21	7	1	91	*Cladophora* *Pithophora* *Spirogyra*
Hydrodictyon	7	1	2	4	Nil	85	*Cladophora* *Spirogyra* *Pithophora*
Pithophora	4	1	1	1	1	75	*Spirogyra* *Rhizoclonium* *Hydrodictyon* *Oscillatoria*
Cladophora	47	12	26	9	Nil	74.5	*Rhizoclonium* *Spirogyra* *Oedogonium*
Spirogyra	34	11	16	6	1	68.0	*Cladophora* *Rhizoclonium* *Oscillatoria*
Sirogonium	2	1	1	Nil	Nil	50	*Zygnema*

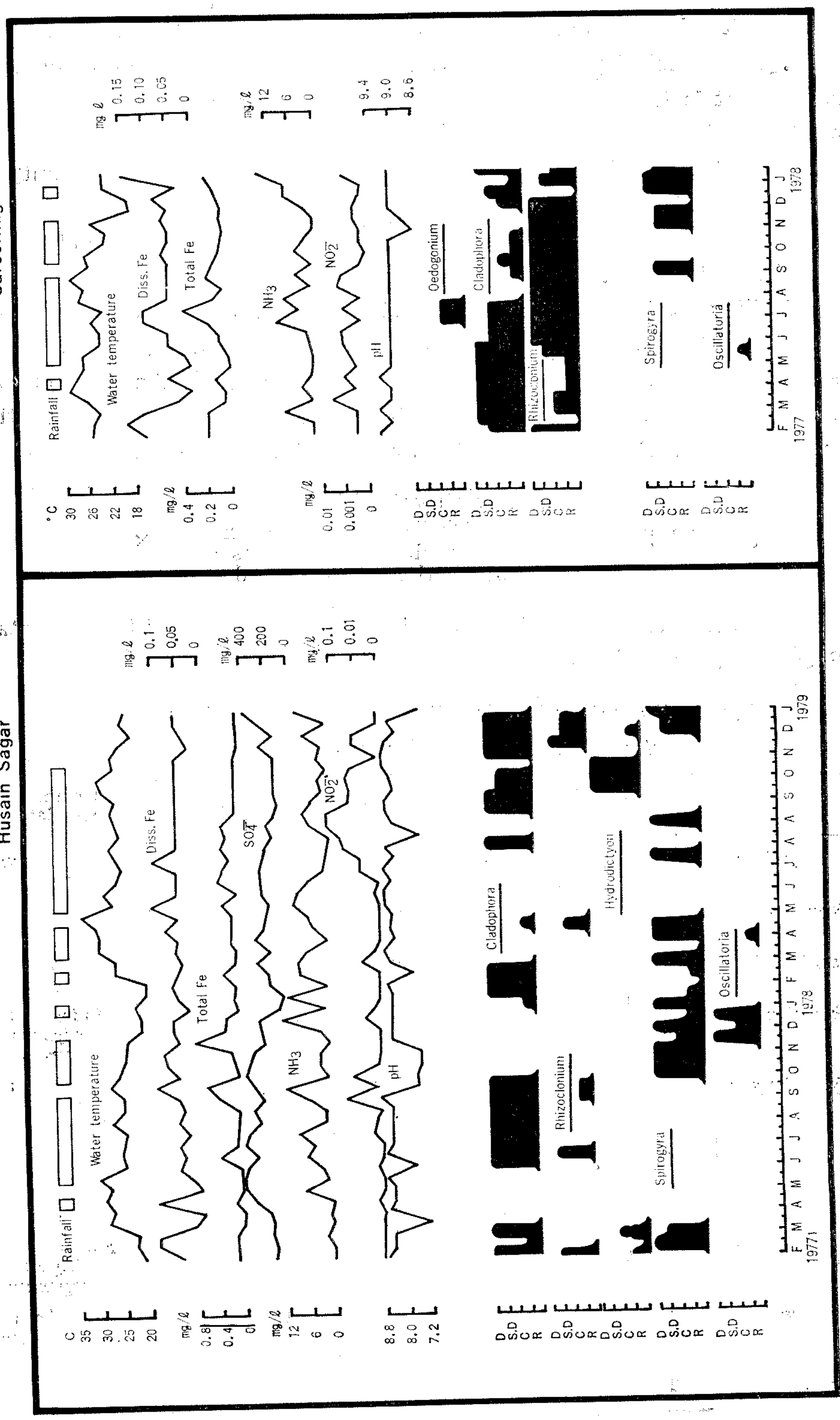

Fig. 1. Filamentous algal mats—Periodicity, (D = Dominant, S.D = Sub-dominant, C = Common, R = Rare)

Most common filamentous algae in waters around Hyderabad were *Cladophora*, *Spirogyra* and *Rhizoclonium*. Interestingly their sociability was compararatively less than that of those which were rather uncommon mat formers such as *Oedogonium*, *Zygnema* an *Oscillatoria*. Another point that emerged out of this study was that the majority of algal mats in this region were bialgal and very rarely polyalgal. Trialgal mats occupied a median position in this respect.

Periodicity

Cladophora, *Rhizoclonium*, *Spirogyra* and *Oscillatoria* were common to both the permanent lakes studied while *Hydrodictyon* was specific to Husain Sagar and *Oedogonium* to Saroornagar. The mat covered a considerable segment of the lake surface all the year round it Saroornagar but Husain Sagar had none whatsoever is summer. May be it was the advere effect of high water temperature which rose to 30–34°C in that lake.

Oedoginium showed only one peak in Saroornagar in the middle of rainy season when temperature was around 25°C. It lasted for about a month or so. *Cladophora* was less sensitive towards temperature in these lakes. It was more or less a 'constant' form in Saroornagar, and was often present in Husain Sagar. Water temperatures more than 26°C restricted its growth in these waters. *Rhizoclonium* showed two peaks per year in Husain Sagar—the first in February and the second in June-July when water temperature was around 22–25°C. Its second peak was more long-lasting and coutinued upton October. The most important factor in its development was temperature. In Saroornagar it was a constant form and disappeared from the surface waters only when temperature fell to about 19°C (Fig. 1). *Hydrodictyon* multiplied once every year in Husain Sagar. This happend either in early summer or towards the end of monsoon when water temperature was 22–28°C. It persisted in surface waters for hardly a month or two and then disappeared. *Spirogyra* showed two peaks of growth per year in both the lakes. These were in early summer and late monsoon season when water temperatures were 23–26°C. *Spirogyra* showed a tendency to multiply in midrainy season also if the temperature regime was suitable. It was adversely affected by the fall in temperature and completely disappeared at 19°C in Saroornagar. *Oscillatoria* and *Hydrodictyon* multiplied once in a year and that was in winter when water temperature reached around 21°C. These algae also showed a tendency to multiply at higher temperature of summer but such peaks were neither significant nor lasted longer than a fortnight.

Apart from the above mentioned physical factors, the chemistry of water also plaped an important role in their periodicity.

Only once did total Fe register a high concentration of 0.4 mg/l in Saroornagar and it was specifically during this period that *Oedogonium* multiplied profusely. Probably Fe along with temperature controlled its periodicity in that lake. *Cladophora* in Husain Sagar reacted sharply to the pH changes. It was abundant when pH was around 8.5. In Saroornagar which always maintained the pH above this range, it was more or less a constant form. The alge was indifferent to the changes in inorganic-N, organic-N, PO_4^{---} and Fe content. Probably pH and temperature controlled its periodicity in these lakes. *Rhizoclonium* appeared to be more tolerant towards NH_3 and NO_2^- content of water. It multiplied when Fe in filtered water was 0.05 mg/l or more in Husain Sagar. In Saroornagar the Fe content of water was maintained at this level all through the year and it showed a definite fall after the continuous growth of this alga which apparently utilized. it. *Hydrodictyon* was very sensitive to pH, CO_3^{--} and HCO^-_3. Whenever CO_3^{--} increased beyond 22 mg/l and HCO_3^- 300 mg/l, it disappeared from the surface water. Apparently it tuilized NH_3 rather than the NO_3^-. This was indicated by its more profuse growith in the second year of observation when water was rich in NH_3 (2–4 mg/l or higher). Water showed almost supersaturation in Oxygn (6–8 mg/l) when *Hydrodictyon* grew. Its profuse growth in the second year of observation also matched with higher concentration of PO_4^{---} (0.60–0.75 mg/l) in Husain Sagar. Prescott (1959) probrbly hinted at this when he said that *Hydrodictyon* spp. were often found as noxious growths in nutrient rich lakes. SO_4^{--} concentrations fell down considerably during the peak development of this specis (Fig. 1).

During the periods of multiplication of *Spirogyra* both the lakes exhibited comparatively higher concentrations of NO_3^- (above 1 mg/l) and PO_4^{---} (0.3 m/l or more). In Husain Sagar whenever NH_3 exceeded 2 mg/l, *Spirogyra* had a setback. It is also worth noting that all the peaks of *Spirogyra* in these data either coincided with or followed the peaks of total Fe content of unfiltered water. May be Fe requirement of the alga is high and proportioned with the larger pigment content of the cells.

The peaks of *Oscillatoria* occurred when water was rich in both inorganic (60–70 mg/l) and organic carbon (4–5 mg/l). Therefor it was not possible to ascertain which source of carbon it preferred. May be it is capable of utilizing both with equal equal efficiency and on this basis it could be classed with mixotrophic organisms. The same tendency was reflected in ite requirement of nitrogen which it apparently met from both NO_3^- (above 1 mg/l) and nitrogenous organic materials (4–8 mg/l). Since none of these were limiting in Hussain Sagar it was inferred that its periodicity was controlled by physical factors such as temperature rather than the chemistry of the lake water.

Variability in biomass

The differences between the estimated biomass parameters, i.e., air-dry weight, loss on ignition, residual ash and pigments are actually the estimates of water and the organic and inorganic component of the algal masses. Their percentages for unialgal mats are given in Table 3 which in the last column also indicates the 'surface spreads'. Evidently *Sirogonium* which contained largest percentage of water also exhibited quite high percentage of organic matter, Chlorophyll-a, Chlorophyll-b and total pigment. The pigment content of *Pithophora* was surprisingly low inspite of it having almost the same percentage of water and organic content. Probably reticulate pattern of chloroplast in that alga leaves behind sufficient space for accomodation of water. Again, *Sirogonium* and *Spirogyra* though quite similar in morphology, differed considerably in their pigment and water contents. Their capacities to accumulate minerals and build up organic materials also differed considerably. *Rhizoclonium* and *Cladophora* had almost identical percentages of water, minerals and organic matter but differed in pigment content. Therefore, it looked there was no correlation between the photosynthetic efficiency of an alga (if assessed on the basis of the percentage of the pigment) and its capacity to accumulate minerals. Interestingly there was a strong negative correlation ($r = -0.8742$, $P = 0.01$) between the horizontal spreading capacity and mineral content. Greater was the mineral content, lesser was the surface spread of an alga. Probably that was a physical phenomenon in which the deposition of minerals in cells increased their weight and reduced the capacity of the alga to spread horizontally.

Table 3. *Average percentages of water, minerals, organic matter and pigment contents and surface spread capacities of unialgal filamentous mats*

Community	Water content	Minerals	Organic matter	Chl. a	Chl. b	Total pigment	Surface spread (mm²)
				air-dry wt.	air-dry wt.	air-dry wt.	
Sirogonium	47.92	10.30	89.58	3.93	3.78	7.71	5.4×10^8
Pithophora	44.30	10.24	89.76	1.97	1.77	3.74	—
Spirogyra	37.29	5.71	77.94	2.20	1.63	3.84	5.5×10^8
Hydrodictyon	32.77	8.78	91.21	3.00	2.06	5.06	3.4×10^8
Rhizoclonium	24.68	58.55	41.45	1.10	1.09	2.20	1.7×10^8
Cladophora	21.98	40.41	59.58	2.31	2.11	4.42	2.4×10^8

Amongst multicellular mats (Table 4) (*Cladophora* + *Hydrodictyon*) association exhibited the highest pigment content, and was probably the most efficient photosynthesizer. In this respect the associations of *Spirogyra*+*Pithophora*; *Cladophora*+*Rhizoclonium*+*Spirogyra*; *Spirogyra* + *Zygnema* and *Spirogyra*+*Cladophora* were least efficient. *Sirogonium*+*Zygnema*; *Spirogyra*+*Oedogonium*; *Spirgyra* + *Oedogonium*; *Spirogyra* + *Oscillatoria*; *Rhizoclonium*+*Spirogyra* and *Cladophora* + *Rhizoclonium* combinations occupied median position from this view point.

Table 4. *Average percentages of water, minerals, organic matter and pigment contents of observed multialgal filamentous mats*

Association	Water content	Minerals	Organic matter	Chl. a air-dry wt.	Chl. b air-dry wt.	Total Pigment air-dry wt.
Sirogonium+*Zygnema*	36.46	34.48	65.58	1.38	0.99	2.37
Spirogyra+*Oedogonium*	31.38	14.55	85.45	1.39	1.26	2.66
Cladophora+*Hydrodictyon*	28.69	16.12	83.96	3.20	2.91	6.11
Spirogyra+*Pithophora*	26.19	10.63	89.37	1.02	0.79	1.81
Spirogyra+*Oscillatoria*	23.93	58.12	41.88	1.09	0.98	2.06
Rhizoclonium+*Spirogyra*	17.76	36.14	63.70	1.25	0.83	2.08
Cladophora+*Rhizoclonium*	17.24	35.96	64.63	1.18	1.13	2.31
Spirogyra+*Zygnema*	14.18	7.22	92.88	0.92	0.66	1.58
Spirogyra+*Cladophora*	13.62	21.66	78.22	0.96	0.77	1.73
Cladophora+*Rhizoclonium* +*Spirogyra*	19.34	20.59	79.40	0.99	0.75	1.75

Production

(1) Hnialgal mats: The day-long rates of production of observed unialgal mats varied enormously from 6.8 to 33.6 mg C/ml/day (Tabl 5). *Spirogyra* showed the highest production average of 27.5 mg/C/ml/day. For *Cladophora* it was 11.5 mg C/ml/day and for *Rhizoclonium* 6.8 mg C/ml/day. It may be reminded that *Spirogyra* mats had stronger tendency to spread horizontally as compared to those of *Cladophora* and *Rhizoclonium*. It also had conspicuously larger amounts of pigments. Thus one may infer that algae with a greater capacity to spread horizontally contain proportionately more pigments and are more efficient photosynthesizers. May be the gas formed during active photosynthesis makes them buoyant (Tiffany, 1951) and also adds to their capacity to spread horizontally.

The rate of carbon assimilation was higher at mid-day (12 noon-2 p.m.) for *Spirogyra* and *Cladophora* (Table 6), but for *Rhizoclonium* it was in the afternoon (3–5 p.m.). Probably photosynthesis in *Rhizoclonium* progressed at a slower pace and reached an optimum only in the later part of the day. That *Rhizoclonium* was comparatively inefficient photosynthesizers was further

Table 5. *Relation between production (mg C/ml/day), pigments (mg/ml) and surface spread (mm²/ml) of unialgal mats*

Algae	Production		Pigments	Surface spread
	Range	Mean		
Spirogyra	21.4–33.6	27.5	26.69	5.5×10^3
Cladophora	8.5–14.1	11.5	11.53	2.4×10^3
Rhizoclonium	—	6.8	7.04	1.7×10^3

Table 6. *Two-hourly production (mg C/ml) of unialgal mats at different times of day*

Algae	Mid-day 12–2 p.m.	Afternoon 3–5 p.m.
Spirogyra	7.12	2.06
Cladophora	2.29	1.54
Rhizoclonium	0.58	1.68

indicated by its low P/B (Production Fresh weight) quotient, and Assimilation Number (Production Chl. a) Table 7.

(2) Multialgal mats: Amongst the observed multialgal mats the combination of *Spirogyra* + *Cladophora* was most productive. When *Spirogyra* combined with *Zygnema* or *Oscillatoria* the fall in production level was surpisingly sharp. Similarly *Rhizoclonium* in association with *Cladophora* or with *Oedogonium* did not assimilate half as much carbon as it was observed in case of *Spirogyra* + *Cladophora*. The efficiency of production of *Spirogyra* + *Cladophora* was also evidenced by its high pigment content and to some extent by higher P/B quotient, but it was not supported by the assimilation number (Table 8). This probably indicated that the production of this mat could have been still higher but for certain limitations in the environment. The highest assimilation was recorded for the mat of *Spirogyra* + *Oscillatoria* from Husain Sagar lake. The combination, however, was neither rich in pigment nor showed photosynthetic efficiency.

Table 7. *P/B, and Assimilation number of unialgal mats*

Algae	P/B	Assimilation number
Spirogyra	0.1218	1.94
Cladophora	0.0829	1.95
Rhizoclonium	0.0245	1.80

Table 8. *Production and related parameters for multialgal mats*

Association	Production mg C/ml/day	Pigments mg/ml	P/B	Assimilation number
Spirogyra+*Cladophora*	33.27	20.72	0.0742	2.90
Rhizoclonium+*Cladophora*	16.49	5.54	0.0799	5.77
Spirogyra+*Oscillatoria*	13.96	3.53	0.0219	7.41
Rhizoclonium+*Oedogonium*	10.72	6.94	0.0176	2.72
Zygnema+*Spirogyra*	9.42	10.95	0.0136	1.47

It is interesting to note that all the multialgal mats except *Rhizoclonium* + *Oedogonium* reached their optimum level of production at mid-day. The decline in the rate of photosynthesis in the afternoon was surprisingly sharp. The combination of *Rhizoclonium* + *Oedogonium* produced at almost the same low level at mid-day and in afteanoon (Table 9)

Table 9. *Two-hourly production (mg C/ml) of multialgal mats at different times of day*

Association	Mid-day 12-2 p. m.	Afternoon 3-5 p. m.
Spirogyra+*Cladophora*	8.46	2.62
Rhizoclonium+*Cladophora*	4.99	0.51
Spirogyra+*Oscillatoria*	3.08	1.57
Zygnema+*Spirogyra*	2.24	0.89
Rhizoclonium+*Oedogonium*	1.77	1.80

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淡水藻叢生態的研究

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本文探討印度海德堡附近淡水藻叢羣落的生態，以及藻叢之初級生產力和表面伸展能力。藻叢中最常見的種類是 *Cladophora*, *Spirogyra* 及 *Rhizoclonium*。然而，它們的羣集度低於 *Oedogonium*, *Zygnema* 和 *Oscillatoria*。*Spirogyra* 易於形成單藻叢，而其他大多數藻類則傾向於形成雙藻叢，只有少數形成多藻叢。周圍溫度下降導致 *Rhizoclonium* 和 *Spirogyra* 的消失。*Cladophora* 和 *Hydrodictryon* 對 pH, CO_3^{--} 和 HCO_3^- 比較敏感。絲狀藻的礦物質含量與表面伸展呈負相關。最能朝水平方向伸展的藻類含有較多色素，因此具有比較強的光合作用能力。*Spirogyra* 的生產速率最高（27.5 毫克碳/毫升/日）而 *Rhizoclonium* 的生產速率最低（6.8 毫克碳/毫升/日）。