

MARKED PERIODICITY IN REPRODUCTION OF THE PANJAB FRESHWATER ALGÆ.

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I MADE a regular collection of the Panjab Freshwater Algæ from July 1929 to May 1930, and since then I have been collecting algæ from December 1934 to December 1935 in Saharanpur District, which is on the boundary line of Eastern Panjab and Western part of the United Provinces and has a climate not very different from the eastern submontane districts of the Panjab, like Hoshiarpur and Gurdaspur. My two years' experience has shown me that there is a marked periodicity in the reproduction of spore-forming Chlorophyceæ which is closely connected with temperature and rainfall conditions.

A passing reference may also be made about those Chlorophyceæ which do not form spores with hard walls. Of these *Hydrodictyon reticulatum* is the commonest in ponds and slow-flowing freshwater streams. Its glistening daughter colonies may be found in nearly all months of the year, when water is found in the ponds and streams, and I have collected it in all stages of development in all months from July to February. I am excluding from consideration here all algæ which are found attached to artificial water-reservoirs and only those are discussed which are found in natural ponds and streams.

Seasons of Northern India.—I have divided a year in Northern India into five seasons: Hot Summer Months, Rainy Season, Autumn, Winter and Spring. Start may be made with the Hot Summer Months which begin from about 15th May and terminate by the middle of July. These months are characterised by dry heat. June is the hottest month of the whole year with a mean temperature of 89°.7 F., while the maximum may be as high as 107°.0 F. In these hot dry months, nearly all the ponds dry up, and only a few streams show a slow trickle of water. Due to absence of water no algæ can be seen in any ponds, while in some perennial streams *Edogonium* may be found in a vegetative condition. Most of the algæ tide over these hot and dry months in the form of thick-walled spores.

II. *Rainy Season*—This may roughly be taken as beginning from the middle of July and ending by the second week of September. Due to the Monsoons, the temperature falls to 85° F. About 7 inches of rain falls in these two weeks, and the ponds and streams become fairly full with water. The maximum amount of rain falls in August, *i.e.*, about 8.5 inches, and all the ponds and streams overflow with water. The water of most of the ponds is usually turbid and muddy in August. The rainy season finishes by the second week of September, the rainfall in these two weeks seldom exceeding two inches, and mostly falling in showers. This is the halcyon season for the Myxophyceæ. On logs of wood light bluish patches of *Aphanocapsa montana* may be commonly seen. *Campylonema Lahoreense* is found mixed with grass in dark brown patches almost everywhere. In water-troughs, bluish-green fascicles of *Schizothrix Mexicana* may be commonly seen intermixed with *Cladophora* and *Rhizoclonium*. On moist pieces of wood, green covering of *Pleurococcus* may also be seen. In some streams, young filaments of *Schizothrix* and *Compsopogen* may be seen, the latter being of purple colour, attached to reeds submerged in flowing water. Young filaments of *Spirogyra* are also seen and in most cases the chloroplasts do not show full maturity. The same may be said about various species of *Zygnema* and *Ædogonium*. It is with considerable difficulty that the last mentioned algæ may be found even in vegetative condition.

III. *Autumn Months*.—These may be taken as beginning with the third week of September and finishing by the middle of November. In the latter part of September the sides of ponds begin to dry up. On the sides of drying ponds *Botrydium* and *Protosiphon* appear in a thick green carpet. In the month of November, *Protosiphon* grows in large numbers on fields which have been lying fallow, in bright green patches, 2–8 yards in diameter. Cyst-formation in the subterranean rhizoidal portion takes place in a week, and then the algæ disappears from view. *Spirogyra* is also seen in a fertile condition in most ponds. I recorded four species of *Spirogyra* in this month, *viz.*, *Spyrogyra condensata*, *S. rivularis*, *S. crassa* and *S. nitida*.

IV. *Winter Months*—By the middle of November it becomes fairly cold in Northern India, and the mean temperature drops to 50°.0. The ponds are usually half full at this time, and the streams and rivers have a regular flow of clear, sparkling, and ice-cold water of the Himalayan snows. In some cold freshwater streams like the Siah Baeen near Jullunder with a swift current of water, *Chantransia chalybea*, *Batrachospermum moniliforme*, *Stigeoclonium variable* and *Cosmopogon* sp. are found attached

to blades of *Typha* in the mid-current. These members of Rhodophyceæ and *Stigeoclonium variable* are provided with well-developed basal cells for attachment. These algæ disappear in December, perhaps due to excessive cold, for the mean temperature may be as low as 45° F. In slowly running streams *Cladophora glomerata* may be seen in big tassels, looking like fox-tails attached to water-plants. All these algæ require a good deal of aeration, and I have noticed that where the current of water becomes very slow, these algæ tend to disappear. Here we may mention the peculiar case of *Cladophora glomerata* which may be seen in the tanks of the Shalimar Gardens, Lahore, growing on shells of Gastropods, which move about in the tanks, and thus aerate the algæ. However, in this case the growth of the alga is not luxuriant, and it appears to be a mere shadow of the *Cladophora glomerata* which grows in running streams. Due to slow locomotion of the Gastropod, the alga becomes thickly encrusted with Diatoms and dust particles. *Cladophora glomerata* also occurs in the water-reservoirs of wells fitted with Persian wheels, where it is constantly aerated by the flow of water from the well.

In December we usually have a rainfall of 1.5 to 2 inches especially in the last two weeks. After the dry months of October and November, this is very welcome, and gives a new lease of life to the algæ growing in ponds. In January the rainfall is more copious and is seldom less than 4.0 inches, and as the temperature is low and evaporation is less, the ponds become fairly full. The months of January and February are ideal for the growth of algæ. Along with the species of *Spirogyra* already mentioned I also found nine other species of the genus *Zygnema* which henceforth is usually seen only in a vegetative condition, can be found in a fertile condition. The commonest species of *Zygnema* is *Z. chalybeosporum* which is seen with plenty of zygospores. *Mougeotia genuflexa* may also be found at this time. Species of *Ædogonium* which I never noticed with ripe oospores in any of the above-mentioned months, produce sex organs with great regularity in the month of February, and most of the filaments show green oogonia and antheridia in the case of macrandrous forms, while the nannandrous forms show numerous androsporangia and nannandria growing on the walls of oogonia.

With the coming of winter-rains in December *Vaucheria sessilis* and *V. geminata* may also be seen in the form of bright green felt-like mats in lawns, gardens and other moist places. Oogonia and antheridia begin to appear in the first week of January, and by the last week of February nearly all the filaments become fertile, being heavily laden with oogonia, antheridia and oospores. *Vaucheria sessilis* is found both in aquatic and

terrestrial habitat, and it is curious that specimens of it collected from ponds at about the same time as from the lawns, proved to be more fertile, each filament being loaded with huge crops of oogonia and antheridia, while in the case of terrestrial specimens very few sex organs were seen.

V. *Spring Months*—Spring season may be taken as beginning with the first week of March. As compared with February there is a marked rise in temperature, the mean temperature in March being 62°.0 F. as compared with 49°.7 F. in February. Just as in spring a young man's fancy is supposed to lightly turn to thoughts of love, most of the algæ also show great reproductive activity. Various species of *Ædogonium* produce heavy crops of oogonia and antheridia, and by the end of March their filaments are laden with red, yellow, and chocolate-coloured oospores. By the middle of April nearly all species of *Ædogonium* bear ripe oospores. I recorded fourteen species of *Ædogonium* in these months all in a fertile condition. *Sphæroplea annulina* also shows numerous green ova in its oogonia in the beginning of March. By the end of March the ova become fertilised and young oospores, green in colour, enclosed in a thin membrane, may be commonly seen. In April the oospores become brick-red in colour with a thick hyaline wall produced into 10–15 spines, and arrayed in three alternate rows in the oogonia. This alga shows such an abundance of red oospores in April that many ponds appear deep red in colour. *Ghosella indica*, a new member of Conjugatæ, described by me as combining the characters of *Debarya* and *Zygnema*, with certain peculiarities of its own, is also found free-floating in dark green masses in the month of March. By the middle of April, *Ghosella* is all fertile and its conjugation canals bulge out with ripe zygospores of an orange-yellow colour. *Sirogonium sticticum* also produces zygospores in April.

Periodicity in Reproduction.—By the end of May most of the ponds begin to dry up, as there is no rainfall; and the mean temperature rises to 81°.0 F. Now the algæ have to face the hot dry spell of three months beginning with May and ending with the middle of July. To meet this contingency, species of *Ædogonium*, *Spirogyra*, *Vaucheria*, *Zygnema*, *Ghosella*, *Sirogonium*, and *Sphæroplea* have produced thick-walled oospores which are capable of surviving the high temperatures of June and July. When the rains start in the middle of July, these oospores begin to germinate and produce young filaments. Then for the next four to five months, most of these algæ show a great vegetative growth with very little reproductive activity. The month of March provides optimum conditions for their reproduction, and probably this may be due to rise of temperature in March after the cool months of January and February. Thus there is a marked

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periodicity in reproduction shown by these algae in Northern India which is connected with more or less distinctly marked seasons. This is a remarkable phenomenon which is not noticeable in England or other temperate countries where the seasons are not so well marked, as we have in Northern India.

Season	Months	Minimum Temperature F.	Maximum Temperature F.	Mean Temperature 8.00 A.M.	Rainfall	Condition of ponds and streams	Algae collected	Remarks
I. Hot Summer Months	15th May	73.4	105.4	86.4	..	Nearly all ponds and tanks dry up.	<i>Cedogonium</i> sp. <i>Cladophora glomerata</i> .	Cedogonium found in perennial streams only.
	June	80.1	107.4	89.7	..			
	15th July	80.2	100.5	87.1	..		<i>Rhizoclonium</i> .	
II. Rainy Season	15th July	80.2	100.5	87.1	7.5"	Ponds and tanks half full. Water turbid.	<i>Hydrodictyon reticulatum</i> . <i>Cosmopogon</i> .	Very few algae with thick-walled oospores are seen in these months.
	August	78.9	97.8	85.2	8.5"	..	<i>Aphanocapsa montana</i> <i>Volvox aureus</i> . <i>Campylonema Lahoreuse</i> . <i>Schizothrix mexicana</i> . <i>Oscillatoria princeps</i> . <i>Cylindrocapsa stagnale</i> . <i>Schizomeris irregularis</i> . <i>Ulothrix oscillarina</i> .	
	15th September	73.4	98.3	81.8	1.5"	All ponds full. Water clears up; the rudiment settles down.		
III. Autumn	15th September	73.4	98.3	81.8	..	Water present in most of the deep ponds.	<i>Botrydium granulatum</i> . <i>Protosiphon botryoides</i> . <i>Pandorina morum</i> . <i>Pithophora Kewensis</i> . <i>Stigeoclonium lubricum</i> . <i>Ulothrix</i> . <i>Cladophora Gloeotrichia</i> . <i>Charaf Nitella</i> . <i>Aulosira fertilissima</i> . <i>Aphanocapsa serpentina</i> . <i>Spirogyra nitida</i> and <i>S. condensata</i> . <i>S. rivularis</i> . <i>S. crassa</i> . <i>Rivularia natans</i> .	Spirogyra becomes fertile.
	October	60.3	94.9	70.8	..	Shallow ponds dry up.		
	15th November	48.2	83.9	57.0	..			

Season	Months	Minimum Temperature F.	Maximum Temperature F.	Mean Temperature 8.00 A.M.	Rainfall	Condition of ponds and streams	Algae collected	Remarks
IV. Winter	16th November	48.2	83.9	57.0	<i>Zygnema</i> sp. <i>Batrachospermum moniliforme</i>	<i>Rhodophyceae</i> show a luxuriant growth in cold fresh water streams.
	December	40.9	72.8	45.3	1.5"	..	<i>Chaitransia chalybea</i> .	
	January	41.0	68.4	45.0	4.0"	Ponds fairly full.	<i>Stigeoclonium variable</i> .	
	February	44.5	72.1	49.7	<i>Aphonochete bulboschæte</i> . <i>Pithophora cactoides</i> . <i>Vaucheria uncinata</i> . <i>Drapernaldia glomerata</i> . <i>Zygnema chalybeosporum</i> . <i>Vaucheria sessiles</i> . <i>V. germinata</i> . <i>Nodularia spumigena</i> . <i>Spirogyra neglecta</i> .	
V. Spring	March	54.5	83.9	62.0	..	Ponds about half full.	<i>Sphaeroplea annulina</i>	Nearly all algae with thick-walled oospores and zygospores are in a ripe condition in these months.
	April	64.5	96.5	75.4	2.0"	..	<i>Sirogonium sticticum</i> . <i>Ghossella indica</i> . <i>Oedogonium urbicum</i> . <i>Oe. cardiacum</i> . <i>Oe. inerme</i> . <i>Oe. sociale</i> . <i>Oe. hirnii</i> . <i>Oe. gracillimum</i> , <i>Oe. oblongellum</i> . <i>Oe. pisanum</i> . <i>Zygnema chalybeosporum</i> . <i>Coleochaete Sontata</i> . <i>C. Soluta</i> . <i>Nodularia spurmigena</i> .	
	15th May	73.4	105.4	86.4	..	Water at the bottom of deep ponds and tanks only.		