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THE DISTRIBUTION OF BLUE-GREEN ALGAE (CYANOBACTERIA) FROM THE PADDY FIELDS OF PATAN AND KARAD TEHSILS OF SATARA DISTRICT, MAHARASHTRA, INDIA

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PLATINUM
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Abstract: The distribution pattern of blue-green algae was studied from paddy fields of Patan and Karad tehsils in relation to physico-chemical properties of soil, viz., pH, electrical conductivity, organic carbon %, available N, P, and K. Paddy field soil samples of 38 localities from Patan and 28 localities from Karad were analysed. One-hundred-and-thirty-seven species belonging to 35 genera of 10 families from three orders were encountered from paddy field soils of both the tehsils. Out of 66 soil samples 93.65% samples showed occurrence of unicellular, heterocystous and non heterocystous forms while 6.34% soil samples showed only non heterocystous forms. *Anabaena* and *Oscillatoria* were found to be of common occurrence. Significant variation was not observed in distribution pattern of blue-green algal forms in relation to physico-chemical properties during successive surveys.

Keywords: Cyanobacteria, heterocystous, physico-chemical parameters, soil samples.

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Author contribution: SJG - Conconceptualized study, collected and analyzed data, wrote final version of manuscript translated in the field, VCK - supervised study, helped in the revision of the manuscript.

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INTRODUCTION

Blue-green algae are the first photosynthetic prokaryotes which emit oxygen in the atmosphere. Cyanobacteria are the connecting link between bacteria, eukaryotic algae, and higher plants. They resemble bacteria in the lack of membrane bound organelles like true nucleus, chloroplast, and mitochondria (Feldgarden & Cohn 2003); and they contain a photosynthetic system like that of eukaryotic algae and green plants (Castenholz & Waterbury 1989).

They contain bluish-green colored pigment phycocyanin where 'cyan' means dark blue, hence the name 'Cyanobacteria' and this pigment in conjunction with green chlorophyll, hence the common name is 'Blue-green algae'. Besides chlorophyll, other pigments also present and giving different coloration to them are carotenoids, phycobilins (phycocyanin, phycoerythrin). They also appear bluish, purple, brown, black and green in color (Kondo & Yasuda 2003).

Blue-green algae are important components of soil microflora in the paddy field. They play an important role in maintaining and improving soil fertility as they have the ability to fix nitrogen. Rice fields provide ideal environment for luxuriant growth of blue-green algae. They are found in paddy field soil throughout the year at various growth stages of the rice crop. The occurrence, distribution and proliferation of those blue-green algae is controlled by the physical and chemical nature of the paddy field soil. These parameters of soil show profound effect on the distribution of blue-green algae (Nayak et al. 2004).

Extensive work on the blue-green algae of paddy fields has been carried out in various regions of India, viz., West Bengal, Kerala, Chattisgarh, Manipur, Mizoram, Uttar Pradesh, Madhya Pradesh, Odisha, Tamil Nadu, and Maharashtra, and in Bangladesh (Banarjee 1935; Goyal et al. 1984; Anand & Revati 1987; Anand et al. 1987, 1995; Sahu et al. 1997; Ahmed 2001; Nayak et al. 2001). There have been some reports on the growth and nitrogen fixation potentials of blue-green algae (Gupta 1964; Prasad & Mehrotra 1980; Santra 1991). Marked variations among the species of blue-green algae from rice field soils of different regions of India have been recorded by Tiwari (1972), Sinha & Mukherjee (1975a,b; 1984), and Anand (1990). The effect of soil pH on the blue-green algal diversity in rice field soils was studied by Singh (1978), Sardeshpande & Goyal (1981b), and Nayak & Prasanna (2007).

Studies on blue-green algal flora from the paddy fields of Maharashtra were undertaken by Gonzalves & Gangla

(1949), Sardeshpande & Goyal (1981a); Kolte & Goyal (1985), Patil & Satav (1986), Madane & Shinde (1993), and Patil & Chougule (2009). Biodiversity of blue-green algae from the paddy fields of Satara District was studied by Karande (2009); and Kamble (2010, 2017). Blue-green algal diversity other than paddy was studied by Kamat (1962, 1963, 1964, 1974); Jawale & Kumawat (2004); Auti & Pingle (2006), and Nikam et al. (2013). There is, however, no report on the blue-green algal distribution pattern in relation to physicochemical properties of paddy soil from Patan and Karad tehsils of Satara District, hence the present work.

MATERIALS AND METHODS

Study Area

For the present work paddy fields were selected from Patan and Karad tehsils of Satara, Maharashtra. Patan is 65km away to the south-west of Satara. It is located at 17.370°N and 73.900°E. Most of Patan Tehsil is hilly with deep valleys while some part is plains. It receives heavy rainfall. Common soil is red lateritic soil, in plains it is black cottony soil while at elevations it is of basaltic and lateritic type. This tehsil is famous for cultivation of local varieties of paddy, viz.: Dombya, Dodkya, Kolambya, Bhados, Panwel, Indrayani, Champakali, Ghansal, Jiresal, Teliansh 6444, Kaveri 888, Krishnakusal, Basmati, and Ambemohar.

Karad is 52km away to the south-east of Satara. It is located at 17.289°N and 74.181°E. Karad city situated at southern part of Satara District near Agashiva, at the confluence of Koyna and Krishna rivers which is called 'Preeti sangam'. The tehsil receives moderate rainfall and the common soil type is black cottony soil. It is famous for cultivation of local varieties of rice, viz.: Indrayani, Rethare Basmati, Pusa Basmati, Hansa, Khadkil Kolhapuri, Kolhapuri R-24, and Kaveri.

Soil samples were collected from paddy fields of study area (Fig. 1). Thirty-eight soil samples from Patan and 28 soil samples from Karad were selected for physico-chemical analysis. About 250g of soil from rice fields were collected randomly from both the tehsils as per Somawanshi et al. (1999). The collected soil samples were brought in the laboratory using polythene bags, dried at room temperature in diffuse sunlight in shade, then crushed with the help of a mortar and pestle, sieved and used for physico-chemical analysis. pH, EC, organic carbon %, available Nitrogen, Phosphorous, and Pottash were analysed following standard methods (Table 2). Physico-chemical parameters of soil from both the tehsils were compared with distribution of blue-green algal flora

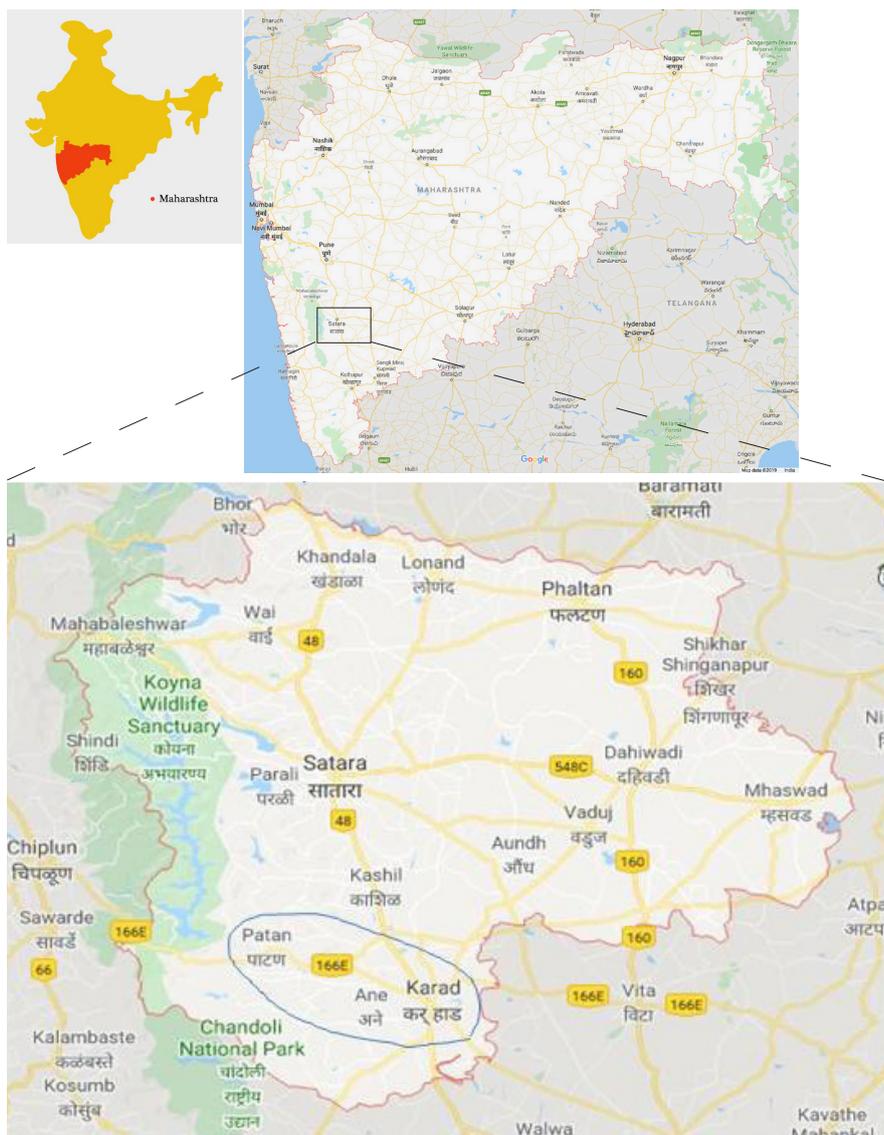


Figure 1. Study area—location of Karad and Patan Tahasils of Satara District. Source: Google maps.

(Tables 3 and 4).

From above sieved soil about 1g of soil transferred aseptically to BG 11 + and BG 11- medium (Rippka et al. 1979), Fogg’s medium and chu 10 medium. We found good results in BG 11 ± medium, so for further culturing and sub culturing we prefer BG 11 ± medium. These cultures were incubated at 22±2°C with 16/8 light dark cycle under 5 Klux intensity of light, after incubation algal growth appeared in enriched cultures in laboratory. Cyanobacterial growth from enriched cultures were examined microscopically and identified with the help of standard literature (Dasikachary 1959; Santra 1993; Anand 1990; Anagnostidis & Komarek 1985). Photographs were taken by using photomicrography unit of Olympus CH20i (Photoplates II, III).

The composition of BG 11 culture media

BG-11 Medium (Allen 1968; Allen & Stainer 1968; Rippka et al. 1979)

Component	g L ⁻¹
K ₂ HPO ₄	0.04
MgSO ₄ .5H ₂ O	0.075
CaCl ₂ .2H ₂ O	0.036
Citric acid	0.006
Ferric Ammonium Citrate	0.006
EDTA	0.001
Na ₂ CO ₃	0.002
Trace Metal Mix (A ₅)	1ml

The trace metal mixture A₅ solution contained the following constituents in

Salts	g L ⁻¹ .
H ₃ BO ₃	2.86
MnCl ₂ .4H ₂ O	1.81
ZnSO ₄ .7H ₂ O	0.222
Na ₂ MoO ₄ .2H ₂ O	0.390
CuSO ₄ .5H ₂ O	0.079
CO(NO ₃) ₂ .6H ₂ O	0.049
pH was maintained in	7–7.5

RESULT AND DISCUSSION

Thorough screening of 66 paddy field soil samples collected and cultured from study area have shown occurrence of 137 species belonging to 35 genera of 10 families from three orders, viz., Chroococcales, Nostocales, and Stigonematales (Table 1). Of the 35 genera isolated from soil samples 11 are unicellular and 24 are filamentous. Among filamentous taxa; 10 were filamentous non-heterocystous and 14 are filamentous heterocystous. Filamentous heterocystous forms are found to be dominant over filamentous non-heterocystous forms. Among the heterocystous form order Nostocales found to be dominant. The abundance and distribution of heterocystous forms may be indicating the lower nitrogen status in study region. Species richness was found in the genus *Oscillatoria*. The most widespread genus from the paddy field soils of study region is *Anabaena* followed by *Oscillatoria* and *Lyngbya*. The observations of the present study do not differ much from those by Anand et al. (1995), where it was reported that the genera *Oscillatoria* and *Phormidium* were predominant in rice fields of Kerala.

Thirty-four genera and 131 species from Patan and 30 genera and 95 species from Karad were recorded (Table 1); 63.50% taxa showed common occurrence, 32.11% taxa restricted to paddy soils of Patan while 4.37% taxa found in paddy field soils of Karad. Nine forms strictly restricted to paddy field soils of Patan, viz., *Synechosystis*, *Westiellois*, *Aulosira*, *Symploca*, *Schizothrix*, *Merismopedia*, *Trichodesmium*, *Cylindrospermum*, and *Dacylocccopsis* while *Polychlamydom* is a rare form restricted to paddy field soils of Karad. Order Nostocales found to be largest order in the family Oscillatoriaceae. Genera *Oscillatoria*, *Lyngbya*, and *Phormidium* belonging to family Oscillatoriaceae and genera *Anabaena* and *Nostoc* belonging to the family Nostocaceae were found to be dominant from paddy soils of both the tehsils.

Analysis of paddy field soils (38 localities from Patan and 28 localities from Karad) by applying standards of soil parameters required for agriculture were conducted (Table 2). Soil analysis showed that pH and EC of majority

Table 1. Total number of species from Patan and Karad tehsils.

Family	Genera	Species in Patan Tehsil	Species in Karad Tehsil
Order Chroococcales			
1. Chroococcaceae	<i>Chroococcus</i>	5	4
	<i>Aphanothece</i>	3	3
	<i>Aphanocapsa</i>	2	2
	<i>Gloeothece</i>	3	2
	<i>Gloeocapsa</i>	6	3
	<i>Synechosystis</i>	1	1
	<i>Synechococcus</i>	2	1
	<i>Microsystis</i>	1	2
	<i>Dacylocccopsis</i>	1	-
	<i>Merismopedia</i>	1	-
2. Entophysalidaceae	<i>Chlorogloea</i>	2	2
Order Nostocales			
1. Oscillatoriaceae	<i>Lyngbya</i>	16	9
	<i>Trichodesmium</i>	1	1
	<i>Oscillatoria</i>	27	20
	<i>Phormidium</i>	12	7
	<i>Microcoleus</i>	2	2
	<i>Symploca</i>	1	-
	<i>Schizothrix</i>	1	-
	<i>Polychlamydom</i>	-	1
2. Microchaetaceae	<i>Microchaete</i>	2	2
3. Nostocaceae	<i>Cylindrospermum</i>	7	2
	<i>Anabaena</i>	9	10
	<i>Nostoc</i>	7	7
	<i>Pseudoanabaena</i>	2	1
	<i>Aulosira</i>	2	-
4. Scytonemataceae	<i>Plectonema</i>	1	1
	<i>Scytonema</i>	2	2
	<i>Tolypothrix</i>	2	1
5. Rivulariaceae	<i>Calothrix</i>	1	2
Order Stigonematales			
1. Mastigocladaceae	<i>Mastigocladus</i>	1	1
2. Nostochopsidaceae	<i>Nostochopsis</i>	1	1
3. Stigonemataceae	<i>Fisherella</i>	2	2
	<i>Hapalosiphon</i>	3	1
	<i>Westiellopsis</i>	1	1
	<i>Westiella</i>	1	1
10 Families	35 Genera and 137 species	34 Genera and 131 species	30 Genera and 95 Species

Table 2. Standard of soil parameters required for agriculture (Somawanshi et al. 1999).

pH	EC	Fertility category	Soil samples showing			
			Organic carbon %	N kg/ha	P kg/ha	K kg/ha
1. Acid soil < 6.0	1. Good soil < 1	1. Very low	< 0.20	< 140	< 7	< 100
2. Good soil 6.00-8.50	2. Poor 1-2	2. Low	0.21-0.40	141-280	7-14	101-150
3. Alkali soil > 8.50	3. Harmful to some crops 2-3	3. Moderate	0.41-0.60	281-420	15-20	151-200
	4. Harmful to most of crops >3	4. Moderate High	0.61-0.80	421-560	21-28	201-250
		5. High	0.81-1.00	561-700	29-35	251-300
		6. Very High	>1.00	>700	>35	>300

of the paddy soils from both the tehsils are in good range (Tables 3 and 4). Organic carbon % from paddy field soils of Patan ranged from 0.31–0.106 %; while that of Karad ranged from 0.73–0.87 % by applying standards of soil parameters; the organic carbon % from paddy field soils of Patan was higher than paddy field soils of Karad (Table 3 and 4). Blue-green algal abundance was recorded to be more in paddy soils of Patan than Karad. The total nitrogen from Patan ranged 150.5–410 kg/ha and that of Karad 61.1–323.4 kg/ha found to be favorable for the distribution of blue-green algal forms. The range of available N from both the tehsils when compared with standards (Table 2) indicated that the low to moderate nitrogen content (Tables 3 & 4) did not affect the blue-green algal abundance. Roger & Kulasooriya (1980) reported that under deficiency of nitrogen in soil condition, nitrogen fixing blue-green algae show their dominance. Our observations are in concordance with those proposed by them.

Available P in Patan ranged 62.7–168 kg/ha and Karad ranged 20.1–56 kg/ha showed blue-green algal abundance. Majority of the localities showed fertility category low to moderate (Tables 3 & 4) when compared with standards from both the tehsils and even though it did not affect blue-green algal dominance. According to Fuller & Rogers (1952), Cyanobacteria are responsible for increased soil phosphorous. Majority of the localities showed average concentrations of phosphorous. Our observations about available phosphorous of paddy soils of Karad support them, but only up to some extent. Available K from Patan paddy field soils ranged 304.6–647.3 Kg/ha and from Karad ranged 145.6–676.4 kg/ha, respectively. Majority localities showed moderate and high range of available K and blue-green algal abundance observed at this range. There is no significant correlation found in concentration of P and blue-green algal distribution from both the tehsils paddy field soils.

Among the soil properties pH is most important factor

which determines growth, establishment and diversity of Cyanobacteria. Blue-green algae generally prefer neutral to slightly alkaline pH for optimum growth (Singh 1961). Our observations support this view as majority of the soil samples from the study area showed neutral to alkaline pH ranging 7–8.40 with occurrence of abundant blue-green algae. pH values of various localities showed significant positive correlation. In culture media the optimal pH for the growth of Cyanobacteria ranges 7.5–10. Abundance of blue-green algae is observed at the pH 6.5–7.5 in our experiments. Low available Nitrogen and Potassium does not affect blue-green algal dominance. Paddy field soil of Patan was rich in organic carbon % while that of Karad showed less organic carbon %. This may be the reason for blue-green algal dominance from paddy soils of Patan area. There was no remarkable role of available phosphorous noted on the blue-green algal dominance from study area.

Different unicellular, heterocystous filamentous and non-heterocystous filamentous forms were isolated, identified and maintained in unialgal culture. Blue-green algal forms were more or less evenly distributed in the rice fields of both the tehsils. Out of 66 soil samples 93.65% samples contained unicellular, heterocystous and non heterocystous forms; 6.34% contained only non heterocystous forms.

Patan is famous for paddy cultivation, traditional cropping system, use of local varieties for cultivation and favorable climatic conditions favours luxuriant growth of paddy in Patan area. Hence we recorded blue-green algal dominance from paddy field soils of Patan. Observations suggested that soil from both the tehsils is nutritionally rich. Understanding of blue-green algal flora and its correlation with soil parameters will help in applying fertilizers, it will also help in enhancing the nitrogen fixing blue-green algae and reducing non nitrogen fixers which usually compete with the all available nutrients with the nitrogen fixers.

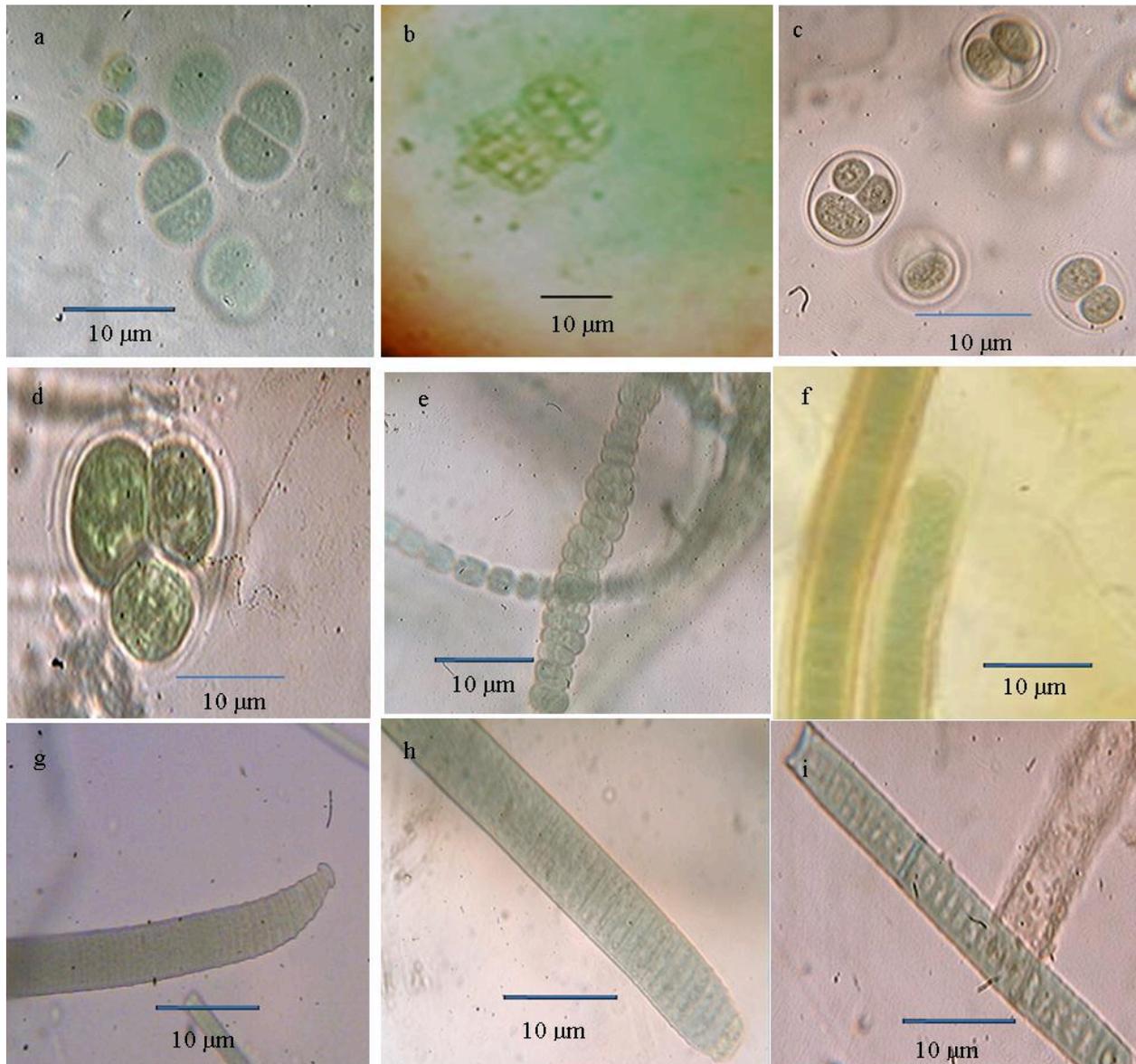


Image 1. a—*Aphanothece pallida* | b—*Merismopedia tenuissima* | c—*Gloeocapsa livida* | d—*Chroococcus turgidus* | e—*Chlorogloea fritschii* | f—*Lyngbya stagnina* | g—*Oscillatoria princeps* | h—*Oscillatoria chalybea* | i—*Symploca thermalis*.

Table 3. Numerical analysis for fertility category of soil samples from Patan Tehsil, Satara District.

	pH	EC	Fertility status	No. of soil samples showing			
				Organic carbon %	Available N kg/ha	Available P kg/ha	Available K kg/ha
1	37 soil samples with Good soil pH; except soil sample of Rasati with acidid i. e. 5.68 pH	37 soil samples have good Ec. Except Soil sample of Konjawde having 1.48 Ec; Which is not good for seed germination	Very low	02	08	-	01
2			Low	13	15	05	01
3			Moderate	04	09	03	02
4			Moderate high	04	03	06	10
5			High	06	02	04	04
6			Very high	09	01	20	20
Total	38	38		38	38	38	38

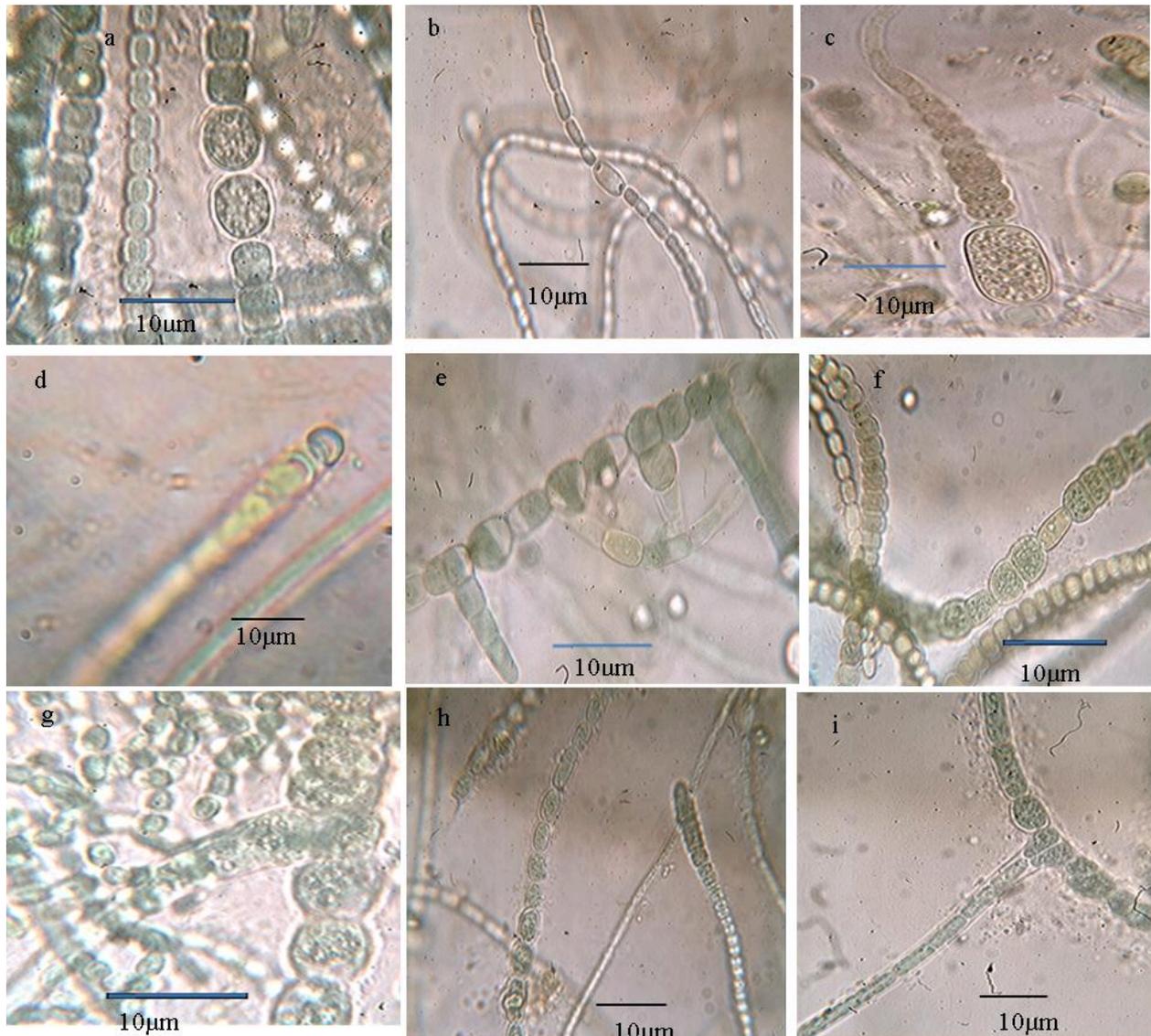


Image 2. a—*Anabaena fertilissima* | b—*Nostoc rivulare* | c—*Calothrix bharadwajae* | d—*Calothrix fusca* | e—*Nostochopsis lobatus* | f—*Fischerella mucicola* | g—*Hapalosiphon flagelliformis* | h—*Hapalosiphon baronii* | i—*Hapalosiphon intricatus*.

Table 4. Numerical analysis for fertility category of soil samples from Karad Tehsil, Satara District.

	pH	EC	Fertility status	No. of soil samples showing			
				Organic carbon %	Ava. N kg/ha	Ava. P kg/ha	Ava. K kg/ha
1	All 28 soil samples with Good soil pH	27 soil samples have good Ec. Soil sample of Talbid having 1.16 Ec; Which is not good for seed germination	Very low	07	08	01	-
2			Low	10	17	05	02
3			Moderate	04	01	05	03
4			Moderate high	06	02	02	02
5			High	-		03	03
6			Very high	01		12	18
Total	28	28		28	28	28	28

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