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RESEARCH ARTICLE

Documentation of algae and physico-chemical assessment of paddy field soil of Belagavi, Karnataka

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ABSTRACT

Algae are the diverse group of organisms in the soil and aquatic environment. The role of them in soil fertility enhancement has been extensively studied worldwide. Belagavi is a tropical agricultural belt in the North Karnataka region with highly fertile soil. Water and soil samples were collected randomly from the paddy field of 15–20 well-distributed spots in 4 selected locations *viz* Kusumali, Jamboti, Kinaye and Piranwadi. The identification revealed the presence of 94 species and 71 genera in the investigated sites. Among all, 62 species belonged to Bacillariophyceae, 14 species to Chlorophyceae, 10 species to Cyanophyceae, 3 to Xanthophyceae, followed by Trebouxiophyceae and Zygnematophyceae (2 species each) and one species of Ulvophyceae. The maximum number of 62 species was recorded from Kusamali, followed by 49 species in Kinaye, 44 in Jamboti and 35 in Piranwadi. The month of February had the highest number of species (61), decreased to 45 in March, 42 in April and 37 in May. Among the physicochemical parameters analysed for the soil samples, it was found that the pH of the soil is slightly acidic in all the study sites ranged between 5.03–5.85. Further, the electrical conductivity (EC) varied from 0.27–0.345 dS/m, found to be in a good range. Estimation of available micro and macronutrients of soil were measured, and it was found to be at low to moderate levels. The present study indicates the extensive distribution of different classes of algae in the rice fields of four study locations in Belagavi.

Introduction

Algae are one of the principal groups of soil microflora in the agricultural fields. It has been found that the growth of algae is directly correlated to the physicochemical properties of soil and water (1). Rice is commonly grown in submerged and water logged environments. The diversified physico-chemical properties of rice field aquatic habitats provide a favorable environment for the growth of various groups of algae (2). These microenvironmental habitats differ physico-chemically and biologically from each other. The heterogeneity of these paddy field ecosystems influences the structure and diversity of microbial communities, and they support a series of microbiological processes (3, 4). Cyanobacteria and diatoms play a key role in agricultural soils as they enhance fertility and they are capable of reducing 30–40 % urea and nitrogen requirement to paddy crops (5). The proper application of cyanobacteria and diatoms in the form of biofertilizer is increasing worldwide, due to the fact that most of them are cosmopolitan in distribution, with a wide range of ecological magnitude to inhabit in the diverse environmental conditions (6).

Diatoms are cosmopolitan in distribution with an estimated number of more than 100000 species (7). They are good ecological indicators of environmental conditions of specific habitats. Some of them are highly tolerant to environmental extremities, while others are highly sensitive to stresses such as freezing and heat desiccation (6). They also significantly contribute to carbon sequestration and play a major role in the recycling of silica (8). Further, they induce a fundamental link between primary and secondary production of food chains in aquatic ecosystems (9).

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The documentation of soil algae, especially of agricultural fields has universal significance. Belagavi District is a tropical agricultural belt in North Karnataka region with highly fertile soil. The documentation of algal species with detailed physicochemical parameters in the paddy fields of the district remained unexplored. In this context, a study was carried out in the selected rice fields of Belagavi taluk.

Materials and Methods

Study area

Belagavi district located in the North-West part of the state between 15°23' to 16°58' North latitude and 74°50' to 75°23' East longitude. Selected study sites are the paddy fields of four villages, *viz* Kusamali, Jamboti, Kinaye and Piranwadi. The location details of all the study sites are given in Table 1. They are situated at the southern part of Belagavi district (Fig.1). The district is between 452 and 900 meters above Mean Sea Level. It is situated near the foothills of Western Ghats (Sahyadri hills) and is bounded by Goa on the west; Ratnagiri, Kolhapur and Sangli of Maharashtra State in the north; Bijapur district on the east and Dharwad and Uttar Kannada districts on the south. The Belagavi district is geographically located in semi-arid Malnad region. On the western side, the district is covered with forests and hills. The eastern plains of the district drained by three rivers, the Krishna in the north, the Ghataprabha in the centre and the Malaprabha in the south. Agroclimatically the district can be divided into three zones, i.e., high rainfall 'Hilly zone', 'Northern transitional zone' and 'Northern dry zone'. The climatic condition of the district is pleasant and characterized by dryness except in the monsoon period. During the summer season, the temperature varies from 38–40°C. In the winter season, the temperature drops to 14–16°C. The average rainfall in the district is 808 mm. Khanapur taluk gets the highest annual rainfall of 1500 mm, whereas least mean annual rainfall is 530 mm in Saudatti taluk. The district has shallow to medium black soil and deep to very deep black soil patterns. It is one of the major rice growing districts of Karnataka State. Moreover, the soil and climatic conditions are ideal for growing paddy, sorghum, wheat and sugarcane. Of the total area of 1338000 hectares, nearly 1000000 hectares are cultivable.

Table 1. Geographic coordinates of study sites

Sl. No.	Study sites	Location (Latitude and Longitude)
1.	Kusamali	15°42' N, 74°23' E
2.	Jamboti	15°41' N, 74°21' E
3.	Kinaye	15°84' N, 74°51' E
4.	Piranwadi	15°51' N, 74°30' E

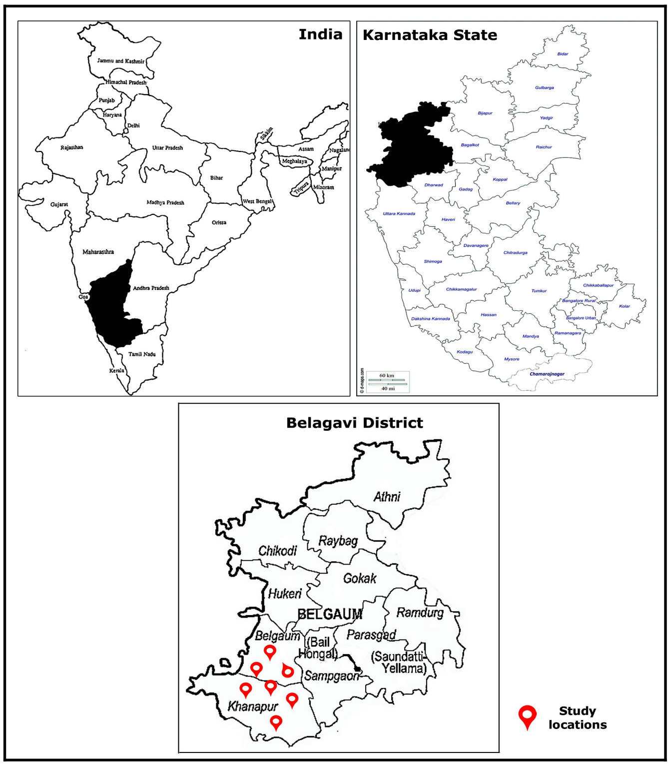

Fig. 1. Study area.

Sampling sites, collection, identification and sample processing

Water and soil samples were randomly collected from 15–20 well-distributed spots with the plot size of 4×4 meters in the paddy fields of Kusamali, Jamboti, Kinaye and Piranwadi locations. About 250 gm soil sample was collected from each spot for algal culture and to carry out the physicochemical analysis. The samples were collected from the month of February to May 2018, on a monthly basis. The soil samples were collected from the depth of 20 cm by means of stainless-steel augers for physicochemical analysis of the soil samples. The soil samples from non-rice cultivated areas (adjacent to the paddy field) were collected and taken as a control for soil analysis. Simultaneously the upper 0.5 cm layer of the soil samples was also collected separately from all the paddy fields for studying the algal species (10). The collected soil samples were brought to the laboratory using polythene zip-lock bags. Further, shade dried in room temperature, crushed with mortar and pestle, sieved and used for physico-chemical analysis. pH, electrical conductivity, available micro and macronutrients like organic carbon%, nitrogen, phosphorus, potash, sulphur, calcium, magnesium, zinc, iron, manganese and copper contents of the soil were determined to check the nutrient content of soil following the standards of soil parameters (11). The soil pH and conductivity were determined by using digital pH meter and conductivity meter, respectively.

Part of the sieved soil samples was maintained by culturing in freshly prepared BG-11±N medium. All the glassware and the media were autoclaved for 20 minutes. The soil samples were incubated at 22±2°C with a 16/8 light-dark cycle under 5K Lux intensity of light for 48 hrs. After incubation, the growth of algae appeared in the enriched cultures (11). Temporary slides were prepared for the identification of algal species using Glycerin solution

(Glycerin 75%: Water 25%) as mountant. Meanwhile, 10 ml of water samples have been collected in screw-capped glass bottles from stagnant water present in the paddy field. A total of 80 samples (20 samples each from all 4 locations) have been randomly collected. The collected water samples were preserved in 4% formaldehyde solution until the further microscopic analysis. The water samples and enriched algal cultures were examined through the microscope (Olympus trinocular microscope, model CX21) and identified with the help of standard literature (12, 13).

Results and Discussion

A total of 94 species and 71 genera were identified from the paddy fields of 4 selected locations in Belagavi (Supplementary Table 1). In the present study, some of the taxa have been identified only up to the genus level because of lacking taxonomic expertise and technical instrumentations for proper identification. In addition, some of the algae did not display the characters required for species level identification at reproductive stage of their life cycle during the field collections. To avoid the discrepancies in the identification of such taxa, they have been enumerated only up to the genus level. Among all the taxa, 62 species belonged to the class Bacillariophyceae, 14 species of Chlorophyceae, 10 species of Cyanophyceae, 3 of Xanthophyceae, followed by Trebouxiophyceae and Zygnematophyceae (2 species each) and one species of Ulvophyceae (Fig. 2A). Similarly among the families, Cymbellaceae reported with maximum number of species (9) followed by Amphiplenraceae, Bacillariaceae, Closteriaceae (5 species each), Desmidiaceae, Gomphonemataceae, Naviculaceae (4 species each), Fragilariaceae and Stephanodiscaceae (3 species each) (Fig. 2B). It could be pointed out that, all these families belong to the class Bacillariophyceae. The most widespread genera

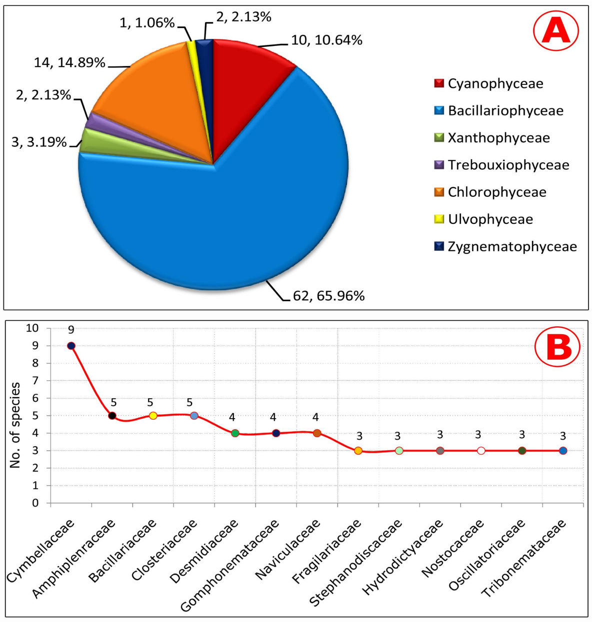

Fig. 2. Distribution of algae based on their class and family **A.** Percentage distribution of different classes of algae; **B.** Top 13 families based on number of species of algae

Cymbopleura reported being dominant with a maximum number of 6 species of the family Cymbellaceae, followed by *Closterium* (5 species of the family Closteriaceae), *Nitzschia* (4 species of the family Bacillariaceae) and *Encyonopsis* (3 species of the family Gomphonemataceae). It is of interest to note that all these genera belong to the class Bacillariophyceae. The observations of the present study do not differ much from the earlier studies carried out (14), where it has been reported that the class Bacillariophyceae, Chlorophyceae and Cyanophyceae were predominant with the maximum number of species in the rice fields of Bhagalpur district of Bihar.

Among the 4 study locations, the maximum number of 62 species was recorded from Kusamali, followed by 49 species in Kinaye, 44 in Jamboti and 35 in Piranwadi (Fig. 3). It was found that out of 94 species identified, 4 species (4.21%) were commonly distributed in all the four locations (*Closterium*

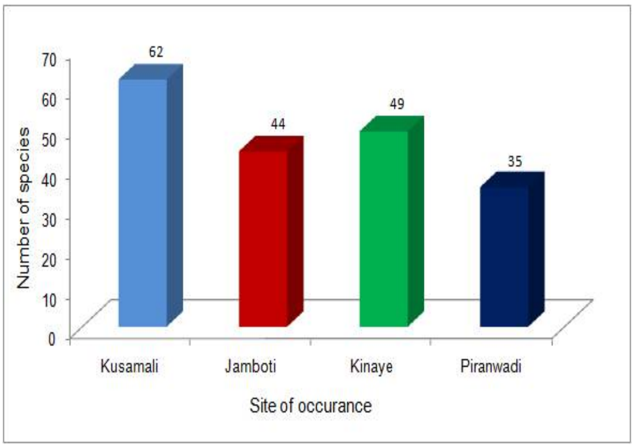

Fig. 3. Total algal species in sampling sites.

acerosum, *Closterium ehrenbergii*, *Cymbella delicatula*, *Oscillatoria princeps*). Whereas, 13 species (13.83%) were restricted to Kusumali, 3 species (3.19%) to Jamboti, 6 species (6.38%) to Kinaye and 5 species (5.32%) to Piranwadi locations.

Altogether, the data obtained from the screening of collected samples revealed that monthly climatic alterations caused the difference in diversity of algal flora in all the four study sites. The highest number of algal species (i.e. 61) were present in the month of February, which gradually decreased to 45 in March, 42 in April and 37 in May, which clearly indicates the number of species positively correlated with the monthly climatic alterations (Fig. 4). The rich diversity of algal species during the month of February may be attributed due to the favourable temperature during this winter season and high nutrient availability. Reports showed that the species of Cyanophyceae are generally sensitive to high sunlight intensities (15). Similar findings were reported for the cyanobacterial diversity from the paddy fields of Iran (16). The Western Ghats belt of Southern India has the most favourable temperature and sunlight during the pre-monsoon season (range 25°C to 35°C), which is optimum for the growth of algal species (13).

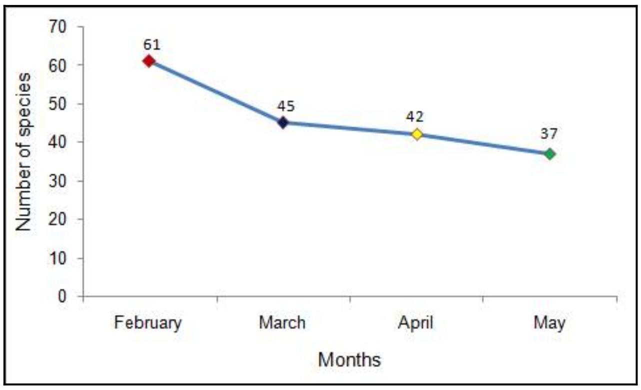

Fig. 4. Monthly distribution of algal species.

The environmental conditions in the culture media are highly different from that is operating in nature; therefore, the qualitative and quantitative growth of algae in nature considerably differ from that of culture media (17). Out of 94 species, 71 species were found only in fresh soil and water samples. Their complete absence in culture conditions was noteworthy. Only 23 species were observed in culture media. *Staurosirella* was the only species which appeared in both culture media and fresh samples. The algal flora of a particular region or crop fields depends on the agroecological conditions and interaction between algal flora and the crop in an agroecosystem (18).

Physico-chemical analyses of the soil of four study sites were made to link the diversity of algal species with the soil conditions (Table 2). The pH determines the solubility of CO_2 and minerals in the medium and directly or indirectly influences the growth, establishment and diversity of algal flora. The pH of the soil varied from 5.03–5.85, *i.e.*, acidic range in four different study sites. The development of soil acidity is generally caused by leaching out of bases and genesis from base-poor acidic rocks or because of continuous usage of chemical fertilizers (19, 20). Further, the electrical conductivity (EC) varied from 0.27–0.345 dS/m, and it is found to be in good range as per the standard soil parameters (11). In case, if the EC grows above 2 m mhos/cm, makes soil salty in nature and harmful to the crops and algal species due to the presence of metal ions (1, 11). These EC values help to improve the diatom and cyanobacterial growth in the different locations of the paddy sites. Further, the organic carbon (%), nitrogen and phosphorus contents of the soil ranged from 0.08–0.64%, 166.33–249.5 kg/ha and 3.8–8.45 kg/ha respectively. They are found to be low as per the standards. Further, the range of available potash varies from 152–272 kg/ha, indicated the low to moderate levels. Meanwhile, the contents like sulphur, calcium, magnesium, zinc, iron, manganese and copper vary from 23.05–71.5 kg/ha, 20.8–35 me/100g, 2.4–8.8 me/100g, 0.99–2.77 ppm, 15.23–95.10 ppm, 37.5–131.4 ppm and 15.95–20.34 ppm respectively. The concentration of nutrients is more important in the diversity of algal species and their population. Availability of phosphorus and nitrogen are important factors that favour the abundance of most of the algae (21). But in the present study, the lower range of available nitrogen and potassium contents did not affect the dominance of Bacillariophyceae and Cyanophyceae isolates in all the four study sites. There was no significant link found in the concentration of nitrogen and phosphorus with the distribution of the species of Bacillariophyceae and Cyanophyceae in the study sites. Our observations are in concordance with the findings of an earlier study from Satara of Maharashtra district (11). There was no significant link found between the concentration of phosphorus and the distribution of Bacillariophyceae, Chlorophyceae and Cyanophyceae.

Table 2. Physicochemical analyses of the soil of four study sites

Parameters	Results				
	Kusamali	Jamboti	Kinaye	Piranwadi	Control
Soil reaction (pH)	5.4	5.03	5.85	5.37	5.85
Electrical conductivity (EC) dS/m	0.345	0.301	0.27	0.28	0.54
Organic Carbon (OC) %	0.08	0.61	0.58	0.64	0.67
Nitrogen (N) kg/ha	166.33	249.5	194.05	187.12	207.91
Phosphorus (P) kg/ha	6.93	8.45	3.8	5.75	69.63
Potash (K) kg/ha	272	158	152	172	134
Sulphur (S) kg/ha	71.5	56.46	49.95	23.05	59.47
Calcium (Ca) me/100g	20.8	24	35	28.2	9.8
Magnesium (Mg) me/100g	4.2	3.8	8.8	2.4	5
Zinc (Zn) ppm	2.77	1.85	0.99	1.03	0.408
Iron (Fe) ppm	15.23	43.82	34.21	95.1	27.88
Manganese (Mn) ppm	65.55	86.2	37.5	131.4	16.41
Copper (Cu) ppm	20.34	15.95	17.46	18.65	1.004

Conclusion

The present study documented a remarkable diversity of algae in four selected locations of Belagavi. Bacillariophyceae, Chlorophyceae and Cyanophyceae were the dominant algal microflora followed by other classes of algae in the study sites. Algal diversity was maximum during the month of February. Cyanobacteria and diatoms play an important role in the maintenance of soil fertility; consequently, play a major role in increasing the growth and yield of the paddy as a natural biofertilizer. In respect to their role in increasing the fertility of the soil, cyanobacteria are of the special academic and applied interest. Therefore, there is further need to explore these study locations with reference to soil fertility, nitrogen fixation, the effect of pesticides on cyanobacteria, diatom and other classes of algae.

Competing Interests

The authors have no competing interests.

Authors' contributions

AM, DS, LM, LP, PJ, SB, SG and US conducted the field visits and collected data. SJ and PB conceptualized the work plan, compiled the data, carried out the research analysis of the work and approval of the final manuscript.

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Supplementary file

Supplementary Table 1

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