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ALGAL DIVERSITY IN TEA AND PINEAPPLE PLANTATION SOILS IN MARNGAR, MEGHALAYA (INDIA)

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ABSTRACT

The algal distribution in farmland depends on the plantation type and soil properties, therefore the present study was aimed to assess the diversity of algal community in soils of tea- and pineapple-plantation soils and to correlate the relationship between algae and soil parameters. Soil samples were collected from tea- and pineapple-plantations every month from April 2022 to May 2023. The soil and algal samples were analyzed by appropriate standard methods. Tea plantation soil was clay loam while pineapple plantation soil was sandy loam. The soil samples from study sites were slightly acidic throughout the season. Significant differences in both the study sites were observed for conductivity, moisture content, water holding capacity, organic carbon and phosphorus content. Some frequently encountered algal species were *Calothrix marchica, Oscillatoria limnetica*, *Phormidium retzii*, *Chlamydomonas reinhardii*, *Scenedesmus communis*, *Scenedesmus dimorphus*, *Gomphonema parvulum*, and *Navicula lanceolata*. A total of 63 algal species were recorded from both the sites. Maximum species diversity was observed in tea plantation soil with diversity index of 2.56. Higher algal abundance was noted in the root zone of tea plantation. The soil physicochemical parameters and plantation type significantly influenced the occurrence, composition and abundance of algae in tea- and pineapple-plantation soils.

Keywords: Algal diversity, physicochemical properties, pineapple plantation, soil, tea plantation

INTRODUCTION

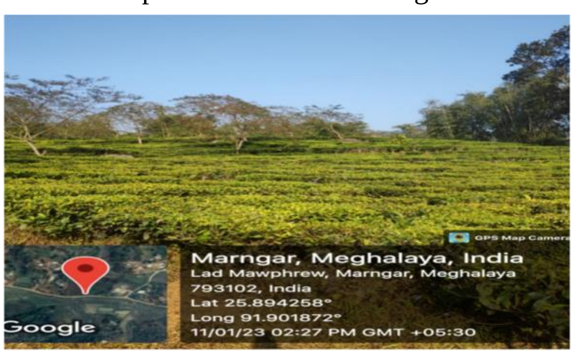
Soil is a natural body having many layers that are primarily composed of minerals, organic matter, etc. which differ from their parent materials in texture, colour, chemical and biological characteristic (Adesalu and Olugbemi, 2015). Algae are important component of soil ecosystem and function and serve as natural bio-indicator for soil health quality (Chamizo *et al.*, 2018). Soil algae promote soil formation and biological processes like dinitrogen fixation, aggregate stabilization, organic matter mineralization, soil water and air retention capacity, etc. (Glaser *et al.*, 2018; Alvarez *et al.*, 2021). The algae are used for soil regeneration and conditioner replacing the chemical or artificial conditioners (Aggarwal, 2020). Algae act as a nitrogen and carbon source for other biota as well as excrete growth promoting substances like hormones, vitamins, amino acids, and organic acids (Wilson, 2006). The distribution of algae in soil is influenced by the soil type, microclimatic condition, and vegetation (Bohlen *et al*., 2001; Joseph and Ray, 2024).

Agricultural lands are susceptible to the loss of soil fertility due to large-scale intensive farming, which may lead to soil degradation of cultivated land. Microalgae account 27% of the total biomass found in agricultural lands (Abinandan *et al.*, 2019). The distribution, composition and abundance of algae in different farmlands are adversely affected by the use of fertilizers, insecticides and pesticides (Dirborne and Ramanujam, 2018). Soil disturbance like tillage strongly affects the algal composition and density, particularly cyanobacteria (Zancan *et al.*, 2006). The various physicochemical properties of soil like pH, moisture content, water holding capacity and nutrient, etc. control the occurrence of soil algal flora (Gabriel *et al*., 2023; Graham and Knelman, 2023). Many researchers have worked on soil and vegetation restoration by using algae that has anthropogenically been disturbed (Carvalhido *et al*., 2021; Oliveir and Maciel-Silva, 2022). The algal community structure varies with season; and their diversity is usually high in summer and low in winter (Wei *et al*., 2023). Understanding the distributional pattern of algal community in different forest system may significantly help in maintaining and protecting the soil algal flora in ecosystem. Pineapple (*Ananas comosus*) is one of the most important crops raised in North Eastern region of India. This perennial tropical plant is mostly grown in the hilly terrain of the region. Tea (*Camellia sinensis*) is a perennial evergreen economic forest crop widely planted in tropical and subtropical regions. Both are important commercial plants of North East India and the research works on soil algal diversity in these two perennial crop plants is very scanty. Therefore, the present work was aimed to study the soil algal diversity in tea and pineapple plantation in North East India.

MATERIALS AND METHODS

Description of study sites

The two study sites selected were tea and pineapple plantations at Marngar town, Ri-Bhoi district, Meghalaya (India) and the study was undertaken for a period of one year (April 2022 to May 2023). The tea plantation site, located in Lad Mawphrew village, Marngar, had geographical coordinates as 25.894258^o N latitude and 91.901872^o E longitude. Various tea cultivars including *Assamica* species (*Camellia sinensis* var. *assamica*) and *Chinensis* species (*Camellia sinensis* var. *sinensis*) grow at the site. The temperatures at the site ranged from 12-18°C with plenty of rainfall throughout the year.



Tea Plantation

Pineapple Plantation

The pineapple plantation located at the same village has geographical coordinates as 25.893692^o N latitude and 91.901872^o E longitude. Pineapple was introduced to this village in early 1980s and the villagers grow a large number of pineapple varieties mainly the 'Queen' and 'Khasi Hills' varieties. The pineapple plants are grown in well-manured soil. The climatic condition is humid subtropical which is directly affected by South West monsoon; originating from Bay of Bengal and Arabian sea.

Sample collection and analysis

Surface soil and the soil from plant root zones were randomly collected from 20 different places in each plantation site and were thoroughly mixed to have a composite homogenous sample for soil analysis. Soil temperature in both plantation sites was recorded using soil thermometer. Soil pH and conductivity were measured by an electronic digital pH meter and electric conductivity meter (model-611), respectively. Soil texture and soil type were determined following the standard method of

Bouyoucos (1962). Soil moisture content was determined by oven-dry basis. Water holding capacity was estimated by using perforated brass dish (Saxena, 1990). Soil organic carbon and total nitrogen and phosphorus were estimated following the standard methods (Allen *et al*., 1974; Anderson and Ingram, 1993). Soil sampling was done at different depths of 0-6 cm that was designated as root zone area and 6-12 cm depth designated as area away from root area zone. The length of soil depth was taken based on shallow rooted crop.

Algal diversity estimation

Soil samples (10 g) from each plantation fields were placed in a conical flask and diluted 100-fold with distilled water. Different culture media like BG-11 for cyanobacteria (Stanier *et al.*, 1971), Guillard medium for diatoms (Guillard, 1975) and bold basal medium for green algae (Stein, 1980) were used.

Identification of algae: For identification and classification of algae, morpho-taxonomic as well as metric characteristic like cell size, cell shape, cell wall, features of filaments, cross wall constrictions, pigmentation, appearance and colour of mucilaginous sheath, filaments characteristic were noted for each algal taxa**.** Taxonomic identification up to species level was carried out with the help of the floral monographs (Desikachary, 1959; Presscott, 1982; Gandhi, 1998; John *et al.,* 2002). The species diversity index was calculated by using Shannon-Wiener diversity index formula:

$$H' = \sum_{i=1}^{s} \text{Pi} \ln \text{Pi}$$

Where; s = total number of species. Pi is ni/N, ln Pi is normal log of Pi, ni = Number of individuals belonging to i^{th} species; N = total number of individual of all the species

The data were subjected to Pearson correlation to determine the relationship between soil algal flora and soil physicochemical properties. Pearson's correlation coefficient was analysed using Microsoft office excel.

RESULTS AND DISCUSSION

Physicochemical properties of soils from tea and pineapple plantations

The soil texture of tea and pineapple plantations was clay loam and sandy loam, respectively (Table 1). The soil pH was acidic (5.0) in tea plantation and slightly acidic (6.5) in pineapple plantation. Gyaneshwar *et al.* (2002) reported that tea growing areas generally have moderately to high acidic soil. Acidic pH in both plantation sites could be attributed to the anthropogenic activities like application of fertilizers, herbicides and pesticides. Similar findings were also reported by Lin *et al.* (2013) and Dirborne and Ramanujam (2017). Soil temperature did not vary between the two sites as both were located within the same geographical area. The higher moisture content (35.4%) and water holding capacity (50.0%) led to maximum conductivity (0.6 mS cm^{-1}) in tea plantation as compared to the pineapple plantation, perhaps due to the soil type difference. Hawkins *et al.* (2017) revealed that sandy

Table 1: Physiochemical properties of soils in tea and pineapple plantations

Parameters	Tea plantation soil	Pineapple plantation soil
pH	5.00 ± 0.12	6.50 ± 0.23
Temperature (°C)	18.00 ± 1.20	19.00 ± 1.10
Conductivity(mS cm^{-1})	0.60 ± 0.02	0.40 ± 0.03
Moisture content (%)	35.40 ± 1.23	30.20 ± 2.45
Water holding capacity (%)	54.00 ± 3.12	52.00 ± 6.45
Organic carbon (%)	3.90 ± 0.34	2.80 ± 0.34
Nitrogen (mg g^{-1})	1.59 ± 0.02	1.52 ± 0.23
Phosphorus (mg g^{-1})	0.66 ± 0.02	0.52 ± 0.03

soil holds less moisture due to low surface contact and lower electrical conductivity. The soils rich in clay have higher electrical conductivity because of its texture that holds a great amount of water. Organic carbon, nitrogen and phosphorus contents were maximum in tea plantation with values as 3.90%, 1.59 mg g^{-1} and 0.66 mg g^{-1}, respectively, as compared to the pineapple plantation. Mukherjee *et al*. (2020) reported positive correlation between organic carbon and nitrogen content in tea plantation in plains of Sub Himalayan West Bengal, India.

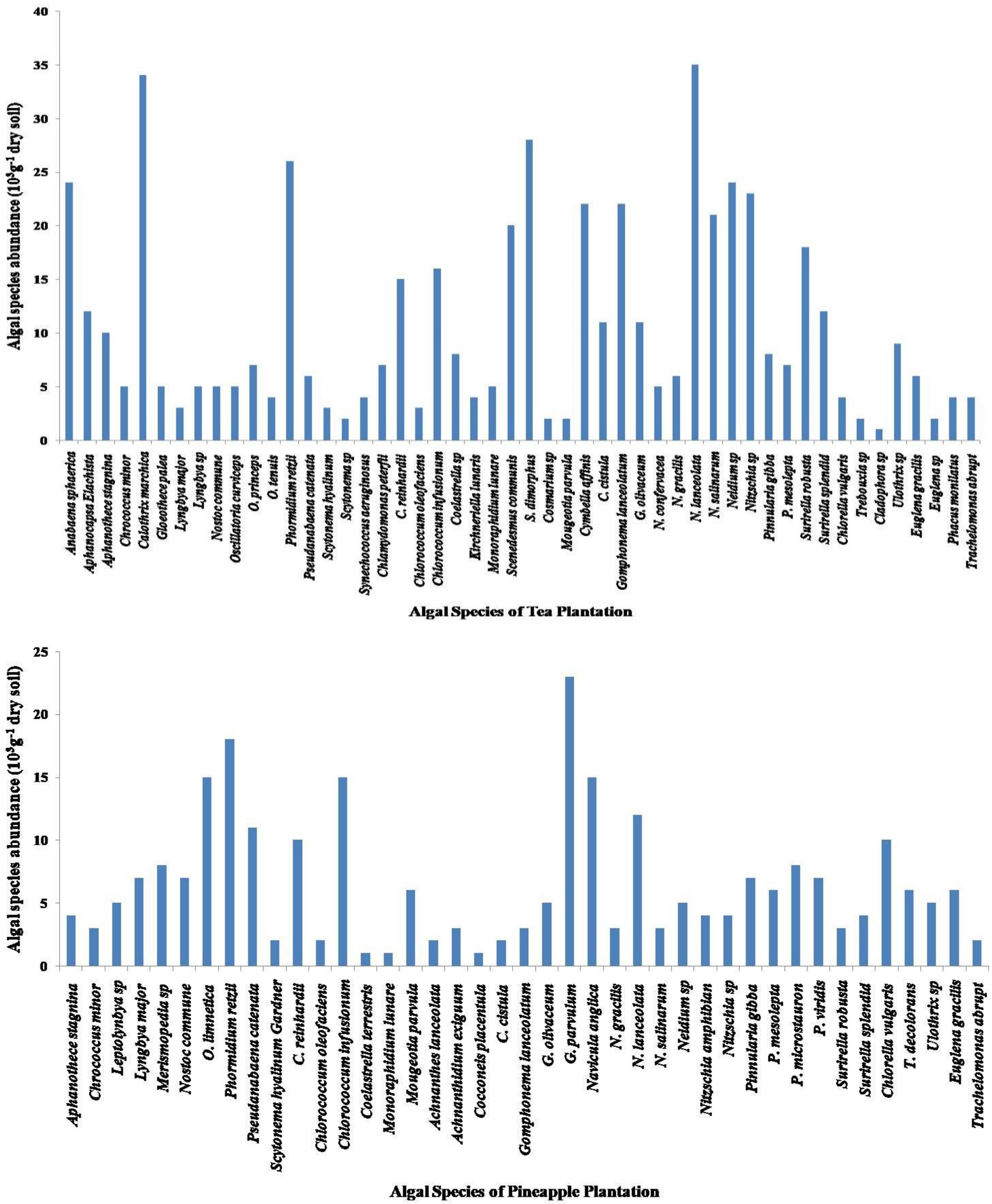


Fig. 1: Distribution of algal species in tea (upper one) and pineapple (lower one) plantations

Algal distribution in tea and pineapple plantation soils

The soil algal distribution varied significantly in two types of plantation. Sixty three (63) soil algal species were recorded from tea and pineapple plantations which belonged to seven classes, mostly dominated by Cyanobacteria and Bacillariophyceae (Fig. 1). Maximum number of species (50) and higher diversity (2.56) were observed in tea plantation as compared to the pineapple plantation soil (Fig. 1 and 2). Similar findings were reported by Adesalu and Olugbemi (2015). Cyanobacteria was dominant group and showed positive response to different agroecosystem and these groups are able to adapt to a vast range of soil structure. Moisture content and water holding capacity have strong positive correlation with all the classes of algae in both fields. Nisha *et al.* (2007) and Lin *et al.* (2013) have reported that soil moisture content plays an important role in algal composition and growth and their germination and reproduction. Maximum algal abundance in root zone was recorded in both the plantation and low abundance was noted in soils away from root zone (Table 2). Krishnamurthy (2000) noticed that algae can undergo considerable adaptation to distinct environmental conditions.

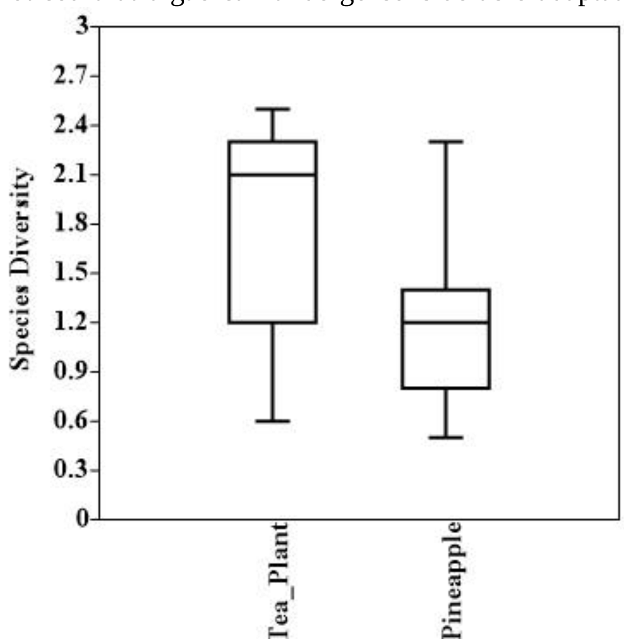


Fig. 2: Species diversity of tea plantation and pineapple plantation

The algal association with plants reveals an ecological and functional complexity (Deepthi and Ray, 2020). The occurrence of higher number of Bacillariophyceae, followed by Cyanobacteria and Chlorophyceae in root zone in both the plantation indicated that root zone favours the colonization of a large number of algae. Hifney *et al*. (2004) also noted the presence of algal flora in root zone of some Egyptian plants and attributed the increase in algal accumulation in root soil of some plants to the root biological activity. The dynamic of soil algal flora is mainly regulated by various physicochemical parameters (Dirborne and Ramanujam, 2017; Agha *et al.*, 2020). In present study, macronutrient like nitrogen, phosphorus and organic carbon showed positive correlation with all the classes of algae (Table 3) and vegetation can enhance and regulate the abundance of soil algae.

Table 2: Algal abundance (10^3 g^{-1} dry soil) in the root zone of tea and pineapple plantations

Algal groups	Tea plantation		Pineapple plantation	
	Root area zone (0-6 cm)	Away from root area (6-12 cm)	Root area zone (0-6 cm)	Away from root area (6-12 cm)
Cyanobacteria	100	60	50	30
Chlorophyceae	80	30	20	15
Zygnematophyceae	5	3	3	0
Bacillariophyceae	150	75	80	40
Trebouxiophyceae	4	0	10	6
Ulvophyceae	6	4	3	2
Euglenophyceae	10	6	4	4

Table 3: Pearson's correlation coefficients between soil physicochemical properties and algal groups in tea and pineapple plantations

Physicochemical parameters	Algal groups*						
	CY	CH	BA	ZY	UL	TR	EU
pH	0.65	0.65	0.67	-0.34	0.23	-0.26	- 0.56
Temperature	0.26	0.34	0.34	0.23	0.34	0.43	0.65
Conductivity	0.46	0.23	0.46	-0.32	-0.23	-0.23	0.62
Moisture content	0.67	0.69	0.54	0.56	0.61	0.57	0.56
Water holding capacity	0.58	0.56	0.55	0.58	0.34	0.56	0.58
Organic carbon	0.67	0.56	0.43	0.61	0.23	0.45	0.45
Nitrogen	0.36	0.34	0.76	0.34	0.67	0.45	0.61
Phosphorus	0.58	0.56	0.34	0.54	0.56	0.48	0.56

*CY = Cyanobacteria; CH = Chlorophyceae; BA = Bacillariophyceae; ZY = Zygnematophyceae; UL = Ulvophyceae; TR = Trebouxiophyceae; and EU = Euglenophyceae

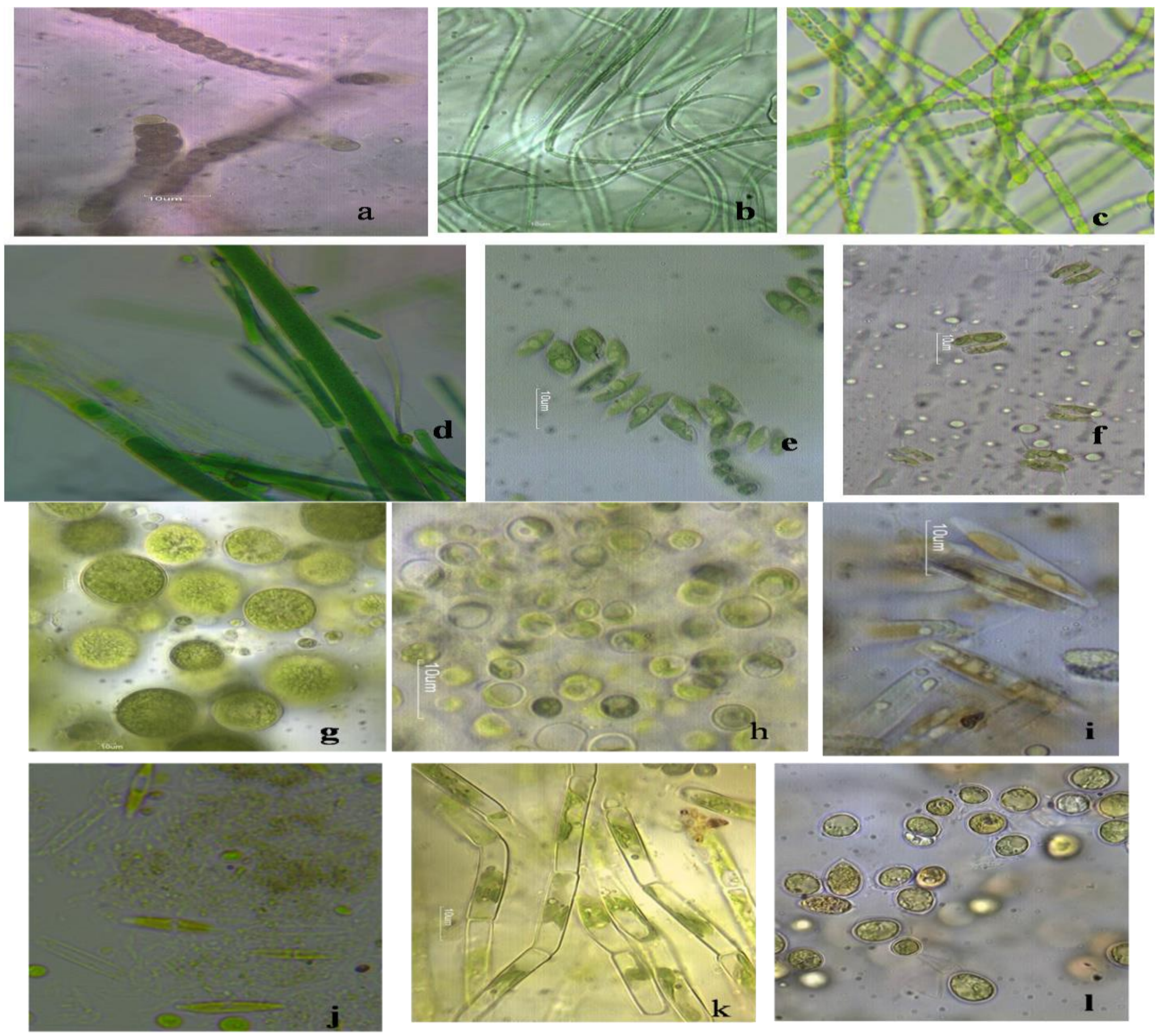


Fig. 3: a) ***Calothrix marchica*****, b)** ***Oscillatoria limnetica*****, c)** ***Anabaena sphaerica*****, d)** ***Phormidium retzii*****, e)** ***Scenedesmus dimorphus*****, f)** ***Scenedesmus communis*****, g)** ***Chlorococcum infusionum*****, h)** ***Chlorella vulgaris*****, i)** ***Navicula lanceolata*****, j)** ***Gomphonema parvulum*****, k)** ***Ulothrix*** **sp., and l)** ***Chlamydomonas reinhardii***

Conclusion: The distribution and diversity of algae in soil was influenced by the type of plantation as well as by the soil physicochemical properties. Tea plantation supported maximum diversity because of dense and higher canopy nature of tea plant and soil macronutrient play an important role in the growth of algal community. The soil algal community was dominated by cyanobacteria and bacillariophyceae. The study provides future perspective to understand the algal assemblage and help in evaluating the effect of different plantation on soil algal communities.

Conflict of interest: The authors declare that they have no conflicts of interest.

Author contributions: Conceptualization, methodology, writing and editing by P.H; sampling and analysis by S.G.L. All the authors have read and agreed to the published version of the manuscript.

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