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Suspended algal communities in high altitude rice wetlands of Apatani Plateau in Eastern Himalaya

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Abstract

The suspended algal life forms (SALF) were studied in the high altitude rice fields (WRF) covering five randomly selected sites of Apatani Plateau in Arunachal Pradesh, India. The samples were collected fortnightly from WRF in three inundated phases *viz.* water accumulation (April- May), flooding (June-July) and early recession (August –September) during the rice growing season of 2013. A total of 62 taxa of SALF belonging to the classes Chlorophyceae, Bacillariophyceae and Cyanophyceae were recorded. *Closterium* sp., *Spondylosium* sp., *Scenedesmus* sp., *Ulothrix* sp., *Zygnema* sp., *Spirogyra* sp., *Docidium* sp. of Chlorophyceae, *Navicula* sp., *Pinnularia* sp., *Rhizosolenia* sp., *Tabellaria* sp. of Bacillariophyceae and *Oscillatoria* sp., *Nostoc* sp., *Phormidium* sp. of Cyanophyceae were in high abundance in WRF. The study also revealed that Chlorophyceae was the most dominant and diverse class of SALF followed by Bacillariophyceae and Cyanophyceae which was ensued for concurrent existence of rice stems as the affixing substrate of attached algal life forms (AALF) in WRF.

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Introduction

Wet rice fields (WRF) form sufficiently rich natural habitat for diversified aquatic organisms (Heckman, 1979; Fernando, 1993). Generally, WRF remain flooded temporarily for about 4-5 months in a year due to accumulation of monsoon water (Fernando, 1996; Saikia and Das, 2004; Mondal *et al.,* 2005). Therefore, by forming a shallow marsh like environment, it becomes highly productive and provides suitable ground for growth of various producers (Fernando, 1993). In general, such rice fields practically show four phases *viz.*, the water accumulation, flooding, recession and drying phases in the context of water depth and rainfall patterns. The algal communities in a typical WRF depict two life forms either as 'phytoplankton' being suspended in water or as 'periphyton' being attached with submerged rice stems (Hansson, 1988; Stevenson, 1996; Das *et al.,* 2007). Hence, being free floating in the water, the suspended algal life forms (SALF) have first access to light, whereas the attached algal life forms (AALF) have the first access to nutrients from the field waters (Wetzel, 1979).

Thus, resource competition between these two life-forms regulates the structure of algal assemblages in shallow WRF (Smith and Kalff, 1983; Hansson, 1988). Moreover, SALF plays the pivotal role in maintaining trophic structure and providing food sources to zooplankton and fishes in WRF (Tas and Gonulol, 2007; Pawar and Sonawane, 2011).

The reviews of literature (Das *et al.,* 2011; Hosmani and Mruthunjaya, 2012) indicated that Chlorophyceae and Cyanophyceae are the most dominant classes compared to Bacillariophyceae within the SALF of WRF and lakes. On the other hand, Senthilkumar and Sivakumar (2008), Bahaar and Bhatt (2011) reported that the class Bacillariophyceae is dominant over Chlorophyceae in paddy fields. Various authors also observed that Chlorophyceae is higher in total counts than the other taxa of planktonic algae in rice fields, ponds, streams and lakes (Ayoade, 2009; Balasingh, 2010; Singh, 2011; Negi and Rajput, 2011; Jemi and Balasingh, 2011; Ssanyu *et al.,* 2011; Nwezei and Ude, 2013). However, perennial and deep water wetlands having less submerged vegetations or substrates hardly possess the scope of assemblages of SALF compared to the transparent shallow water rice field which allow sufficient lights to strike the bottom of the field.

The benthic algae along with AALF colonize on rice stems being suitable substrate for their growth in WRF (Lucinska, 1979; Moss, 1998; Stanley *et al.,* 2003; Saikia and Das, 2009). Accordingly, Baba *et al.* (2011), Reza and Arash (2012), and Duncka *et al.* (2013) confirmed that Bacillariophyceae was the most dominant class among AALF in Sindh river of Kashmir valley and in some wetlands of Brazil and Iran. However, the information regarding the occurrences and richness of SALF particularly in mountain WRF are very meager till date.

With this backdrop, an investigation was carried out in mountain WRF during water accumulation phase (WAP), flooding phase (FP) and early recession phase (ERP) of the rice growing season, 2013. The standard sampling method was adopted for enumeration of SALF from the field water. This article is thus intended to discuss on the richness and diversity of algae into field water as well to appraise the reasons behind their occurrences and variations in such a seasonal ecosystem.

Materials and methods

Study site

The study was carried out in high altitude wet rice fields of Apatani plateau, located in Lower Subansiri district of Arunachal Pradesh, India (Fig. 1). Geographically, the area was located at $26^{\circ}50'$- $98^{\circ}21'$ N latitude and $92^{\circ}40'$ - $94^{\circ}21'$ E longitude and with altitude about 5000 ft. above mean sea level. A total of 15 rice fields were randomly selected from the five villages namely, Mudang tage, Dutta, Nenchalya, Pine grobe and Tajang. These high altitude flooded rice fields have an average water depth of 16-20 cm under emergent rice canopy.

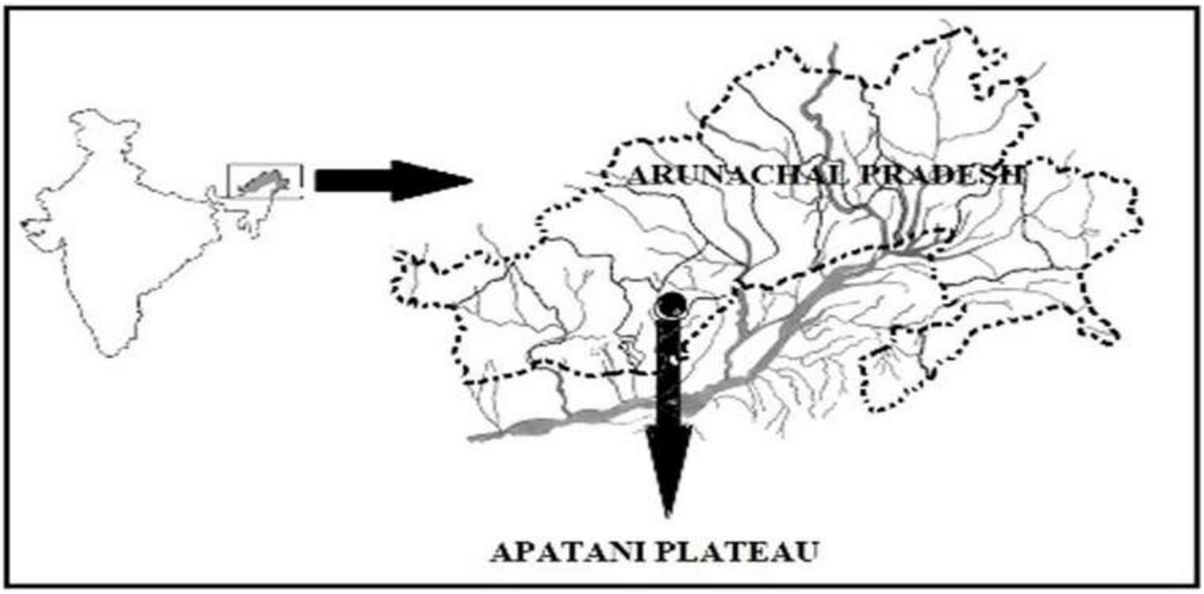

Fig. 1. Location map of sampling site in Arunachal Pradesh.

Analysis of SALF and water qualities

The SALF samples were collected fortnightly by sieving 25 L of rice field water through plankton net made up of bolting silk (mesh size 60μm) starting from the month of WAP till to ERP. The samples were preserved in 4% neutralized formalin and were further analyzed both qualitatively and quantitatively under a binocular light microscope (Nikon, ECLIPSE E200) using10X and 40X objectives respectively. The quantitative analyses of SALF were done with the help of drop count method (Lackey, 1938) and values were expressed as individual per cent litre. Standard identification keys and monographs were used for confirmation of genera or species level identity of individuals (Belcher and Swale, 1976; Turner, 1978; Tonapi, 1980; Penticost, 1984; Desikachary, 1989; Edmonson, 1992). Physico – chemical parameters of field water like alkalinity, dissolved oxygen (DO), biological oxygen demand (BOD), free dissolved carbon di oxide ($FDCO_2$), chloride, Ca hardness (CaH), total hardness (TH), nitrate - Nitrogen and phosphate –Phosphorus were also analyzed (APHA, 2012) from each of the study fields. The water temperature (WT), water depth (except refuge trenches), pH, specific conductivity (SC) and total dissolved solid (TDS) were recorded on spot at each field trip using standard equipment like thermometer (ZPHI-9100 Zico), centimeter scale, digital water analyzer (Systronics 371) respectively. Besides, random sampling for estimating rice stand densities were undertaken following quadrate count method (Catling, 1987).

Statistical analysis

The variation in total SALF was estimated by two-way ANOVA assuming classes and phases as two factors. Shannon and Simpson indices were employed for estimating diversity, while evenness and species richness were computed using Buzas Gibson evenness index and Margelef index respectively. To compare the diversities of different communities the estimated diversity indices were subjected to pair-wise permutation tests in two ways (i.e. within class between seasons and between classes within season). All the analyses were performed using PAST software, 3.02 version.

Results

The high precipitation of actual rainfall data of 2013 was peak in the month of May and August during the rice growing period. Similarly, the average rainfall pattern of last ten years (2002-12) of the plateau area depicted the high precipitation from April to September in general (**Fig. 2**). Actual rainfall and the pattern of rainfall indicated clearly the constant accumulation of water in rice fields of the study area.

The results unfolded that the stand density (8.97m^{-2}) and water depth (3.7 cm) were rising from WAP which attained maximum level of 136.94 $m^{-2}$and 16.9 cm in FP, and again declined a little in the ERP **(Fig. 3)**. A significant positive correlation (**Fig. 4**) between stand density and SALF ($r=0.998$, $p<0.01$) was evident. Variation of physico-chemical parameters of water (**Table 1**) were analyzed fortnightly in three different phases of WRF. The mean value of water physico – chemical parameters like WT, pH, SC, TDS, DO, BOD, Nitrate – N, Phosphate –P, Alkalinity, TH, CaH, $FDCO_2$, Chloride were ranged 22.00-29.00°C, 6.38-6.62, 583.27-520.10 μScm^{-1}, 352.95-292.15 mg L^{-1} , 11.55-4.32 mg L^{-1},3.38-10.23 mg L^{-1}, 2.06-2.70 mg L^{-1}, 0.03-0.21 mg L^{-1}, 24.85-39.82 mg L^{-1}, 15.85-29.00 mg L^{-1}, 9.85-12.03 mg L^{-1}, 11.67-21.63mg L^{-1}, 26.92-39.80 mg L^{-1} respectively during study period.

Table 1. Average range of water physico – chemical parameters in high altitude rice wetlands of Apatani Plateau during rice growing season.

Parameters	WAP (Mean ± SD)	FP (Mean ± SD)	ERP (Mean ± SD)
WT (°C)	22.37±1.72	27.55±0.70	29.62±1.80
pH	6.38±0.42	6.48±0.21	6.62±0.22
SC (μScm^{-1})	583.27±63.57	557.80±55.49	520.10±89.62
TDS (mg L^{-1})	352.95±13.85	292.15±23.01	295.80±33.80
DO (mg L^{-1})	11.55±1.12	5.31±1.58	4.32±2.12
BOD (mg L^{-1})	10.23±0.89	3.38±0.85	3.46±1.49
Nitrate-N (mg L^{-1})	2.70±0.66	2.25±1.13	2.06±0.68
Phosphate P (mg L^{-1})	0.03±0.02	0.16±0.25	0.21±0.23
Alkalinity (mg L^{-1})	24.85±0.39	30.37±7.24	39.82±2.85
TH (mg L^{-1})	21.35±6.62	15.85±2.08	29.00±4.59
Ca H (mg L^{-1})	11.71±1.24	9.85±0.31	12.03±1.64
Free CO_2 (mg L^{-1})	21.63±1.81	13.53±2.63	11.67±1.90
Chloride (mg L^{-1})	26.92±7.80	31.63±14.50	39.80±5.01

The study revealed the presence of total 62 taxa of SALF belonging to three major classes namely, Chlorophyceae (31), Bacillariophyceae (25) and Cyanophyceae (6). It was demonstrated that *Closterium* sp., *Spondylosium* sp., *Scenedesmus* sp., *Ulothrix* sp., *Zygnema* sp., *Spirogyra* sp., *Docidium* sp. under Chlorophyceae, *Navicula* sp., *Pinnularia* sp., *Rhizosolenia* sp., *Tabellaria* sp. under Bacillariophyceae and *Oscillatoria* sp., *Nostoc* sp., *Phormidium* sp. under Cyanophyceae were the dominant genera (Table 2) during the study period. Two-way ANOVA revealed that phases do not have any significant effect ($p>0.05$) on the variation of SALF. Hence, only class-wise total individuals are presented within each phase, where Chlorophyceae always showed the highest values (Fig. 5).The diversity and richness values of the classes were also calculated within each phase. The diversity values showed insignificant results ($p>0.05$, data are not presented) when analyzed between seasons within class. So, the values between classes within season are presented separately (Table 3).

There was significant variation for all the measured indices ($p<0.0001$), except Buzas Gibson evenness index. In case of WAP and FP, Buzas Gibson evenness was found to be significant in only two instances *viz.*, between Chlorophyceae and Bacillariophyceae, and between Chlorophyceae and Cyanophyceae, where Chlorophyceae always had lower evenness (Table 3). On the other hand, in ERP, significant results were obtained in all the three classes where Chlorophycean algae had the lowest and Cyanophycean algae had the highest evenness value. Margalef index revealed that the species richness was in the order of Chlorophyceae>Bacillariophyceae>Cyanophyceae.
Finally, Shannon and Simpson indices precisely explained that Chlorophyceae was the most diverse class, while Cyanophyceae was the least in all the three phases during this study.

Table 2. Individuals of SALF (ind CL-1) in high altitude rice wetlands of Apatani Plateau during rice growing season.

Sl. No.	Cholorophyceae	WAP	FP	ERP
1.	*Arthodesmus curvatus*	333.33	555.55	-
2.	*Closterium longissima*	-	222.22	-
3.	*Closterium setacoum*	-	111.11	111.11
4.	*Closterium* sp.	1944.44	3555.58	2111.11
5.	*Cosmerium obsulatum*	111.11	333.33	-
6.	*Cosmerium* sp.	-	1477.78	333.33
7.	*Docidium sceptrum*	-	666.70	666.70
8.	*Docidium setigorum*	222.22	-	-
9.	*Docidium swartzii*	972.23	2111.11	111.11
10.	*Docidum* sp.	6444.45	5233.33	7888.90
11.	*Euastrum* sp.	-	1666.70	2111.11
12.	*Euastrum verrucosum*	555.56	222.22	333.34
13.	*Gonatozygon reticulatum*	-	222.22	-
14.	*Gonatozygon* sp.	1888.90	2444.44	4222.22
15.	*Micrasteias denticulata*	333.33	-	-
16.	*Micrasteras rotata*	-	-	222.22
17.	*Micrasterias americana*	-	999.99	-
18.	*Micrasterias* sp.	1444.44	1111.11	1444.44
19.	*Microspora* sp.	1555.55	333.33	1000.00
20.	*Odogonium* sp.	666.66	1888.89	2444.45
21.	*Spondylosium* sp.	2833.33	4777.78	12777.78
22.	*Pleurotaenium trabecula*	-	111.11	111.11
23.	*Scenedesmus* sp.	3888.89	1444.44	7333.33
24.	*Spirogyra inflata*	4222.22	6888.89	4677.78
25.	*Spirogyra* sp.	14222.22	24111.12	32444.45
26.	*Spirotaenia* sp.	111.11	-	111.11
27.	*Spirotaennia truncuta*	222.22	777.78	-
28.	*Triploceras gracile*	111.11	66.66	555.55
29.	*Triploceras* sp.	1777.78	1922.15	888.89
30.	*Ulothrix* sp.	6555.11	2666.71	11888.89
31.	*Zygnema* sp.	7888.89	15555.56	10000.00
Sl. No.	Bacillariophyceae			
1.	*Achanthes* sp.	444.44	222.22	777.78
2.	*Cocooneis* sp.	222.22	444.44	222.22
3.	*Cymbella angustata*	111.11	777.78	-
4.	*Cymbella lanceolata*	-	555.55	111.11
5.	*Cymbella longissima*	-	555.55	666.67
6.	*Cymbella* sp.	444.44	555.55	111.11
7.	*Diatoma* sp.	444.44	444.44	444.44
8.	*Fragillaria* sp.	-	444.44	1111.11
9.	*Gyrosigma* sp.	777.77	1000.00	666.67
10.	*Navicula lanceolata*	222.22	-	-
11.	*Navicula placenta*	-	555.55	1000.00
12.	*Navicula* sp.	222.22	2444.44	4333.34
13.	*Navicula viridula*	333.33	-	111.11
14.	*NItzchia* sp.	333.33	222.22	-
15.	*Pinnularia brevistriata*	-	111.11	-
16.	*Pinnularia vulgaris*	1277.77	6222.23	5666.65
17.	*Rhicosphenia* sp.	-	-	333.33
18.	*Rhizosolenia* sp.	1333.33	888.88	1555.55
19.	*Rhopalodia* sp.	-	222.22	-
20.	*Stauroneis* sp.*phoneiocentron*	-	111.11	-
21.	*Tabellaria* sp.	1333.33	3333.34	888.89
22.	*Penium* sp.	2555.56	2111.11	9666.66
23.	*Netrium digitus*	-	222.22	-
24.	*Netrium* sp.	933.33	666.70	777.80
25.	*Mesotaenium* sp	999.99	2111.11	5333.33
Sl. No.	Cyanophyceae			
1	*Anabaena* sp.	333.33	555.55	2000.00
2	*Cylindrospermum* sp.	444.44	222.22	-
3	*Nostoc* sp.	2000.00	555.55	1666.67
4	*Oscillatoria* sp.	888.88	999.99	888.89
5	*Phormidium* sp.	1777.78	4911.11	5333.33
6	*Spirulina* sp.	555.55	333.33	999.99

Discussion

In WRF the occurrence and diversity of the SALF are regulated by complex interactions of multiple factors (Heckman, 1979; Dalkiran and Dere, 2006). The environment itself possesses location specific variability of nutrient concentrations, water conditions, rainfall patterns and influx of light intensities along with physical surroundings of the locations (Fonge *et al.,* 2012; Kumar and Sahu, 2012). The average ranges of water physico-chemical qualities obtained were suitable for the growth of SALF in high altitude WRF (Saikia and Das, 2010). After field preparation, the decomposition of organic matters may influence the water quality with higher value of $FDCO_2$, pH, and SC. Increased mean value of pH in ERP might have caused better growth of certain genera of SALF (Thirugnanamoorthy and Selvaraju, 2009). According to Saikia and Das (2004) location specific high rainfall plays an important role for maintaining the water depth of the WRF of Apatani plateau. The gradual increase of water depth from 3.0-5.0 cm at the WAP up to 20.0 cm or more at FP is favorable for concurrent rice- fish culture (Hora and Pillay, 1962; Saikia and Das, 2010).

Table 3. Diversity indices between three classes of SALF within in high altitude rice wetlands of Apatani Plateau during rice growing season.

Estimated Indices	WAP			FP			ERP		
	Chlorophyceae	Bacillariophyceae	Cyanophyceae	Chlorophyceae	Bacillariophyceae	Cyanophyceae	Chlorophyceae	Bacillariophyceae	Cyanophyceae
Shannon	2.67	2.31	1.59	2.57	2.25	1.17	2.48	2.09	1.37
Simpson	0.89	0.88	0.76	0.87	0.83	0.55	0.88	0.82	0.69
Bujaz Gibson evenness	0.53	0.78	0.81	0.42	0.52	0.53	0.44	0.54	0.79
Margelef	2.96	1.81	0.78	3.31	2.25	0.75	2.77	1.87	0.57

The simultaneous rise of substrate density with more surface area having AALF depressed the growth of SALF by reducing the outflow of dissolved nutrients from the mineralization zone of the substrate surface (Das *et al.,* 2007). On the other hand, SALF reduced the growth of AALF by diminishing the amount of light reaching to the substrate where light and the nutrient competition were the major factors for the growth of SALF and AALF (Hansson, 1988).

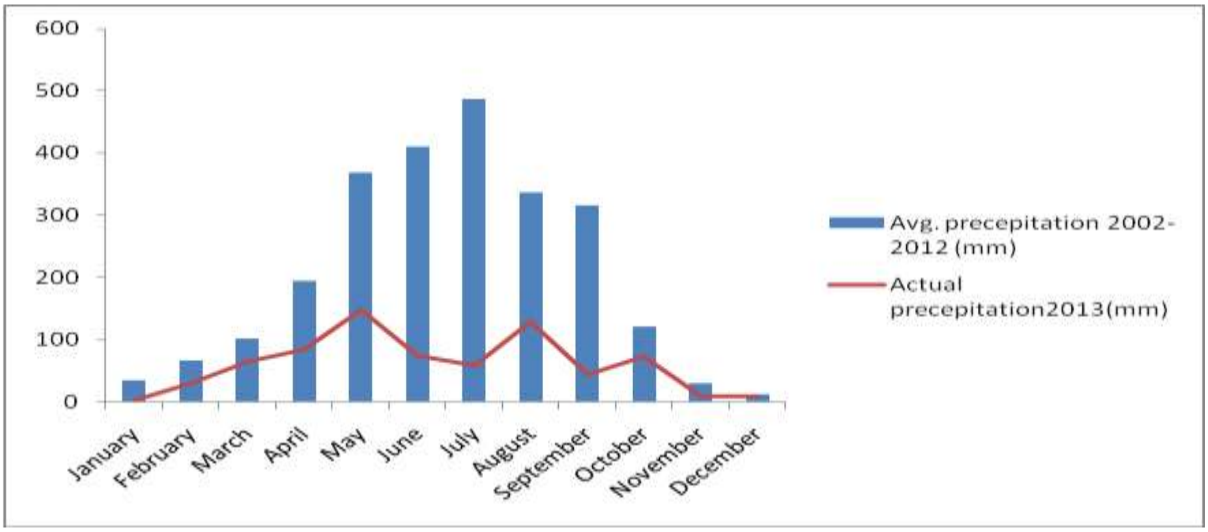

Fig. 2. Average rainfall pattern in last ten years (2002-12) and actual rainfall pattern in high altitude wet rice fields of eastern Himalaya during rice growing season, 2013

Interestingly, among AALF Bacillariophyceae was more dominant on submerged rice because of getting sufficient surface area for growth in shallow WRF. Moreover, high amount of silica in the rice stems influenced the growth of Bacillariophyceae (Lukaw *et al.,* 2012) because it was essential nutrient for the formation of frustules. Morphological and physiological nature of rice stand might have also influenced the development of AALF, as the submerged rice had the ability to secrete mucilage to form stalks or mucilaginous matrices, allowing attachment to substrates (Fritsch, 1945; Round, 1991). However, in suspended condition, algal communities have shown comparatively less population where Chlorophyceae was the most dominant as well as diverse class (Das *et al.,* 2007).

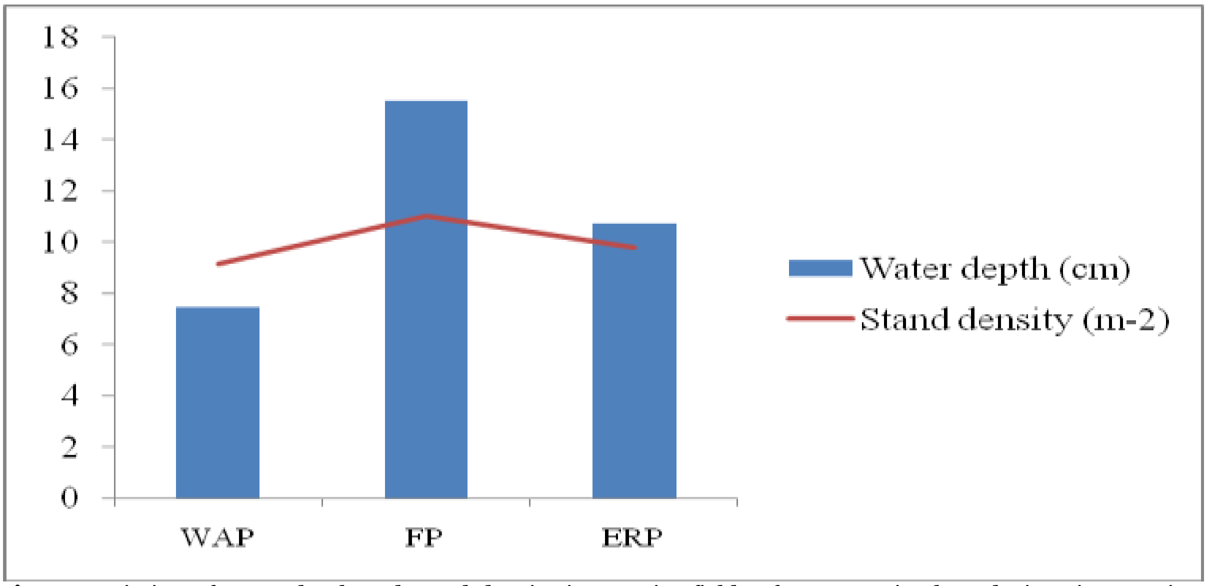

Fig. 3. Variation of water depth and stand density in wet rice fields of eastern Himalaya during rice growing season, 2013.

This phenomenon could be explained by the fact that, better habitat conditions like slightly acidic nature of water with shallow depth and greater quantity of dissolved organic matters particularly the excreta of pig and other domestic animals might have influenced the higher diversity of Chlorophyceae in all the three phases (Saravanakumar *et al.,* 2008; Thirugnanamoorthy and Selvaraju, 2009; Ponce *et al.,* 2010; Mustapha, 2010; Nweze and Ude, 2013**)**.

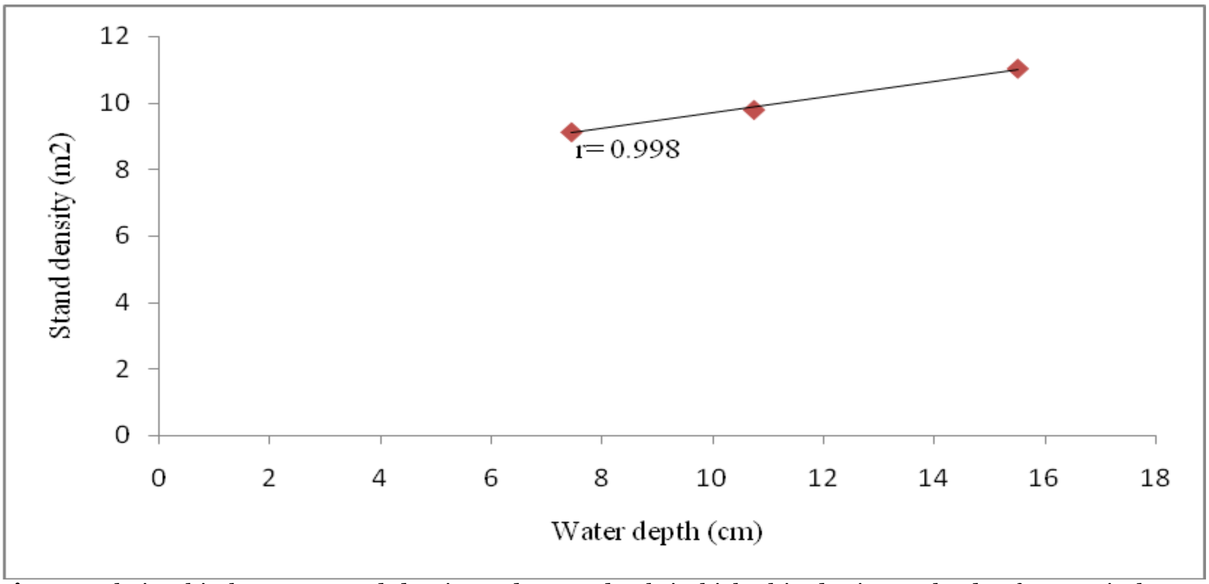

Fig. 4. Relationship between stand density and water depth in high altitude rice wetlands of Apatani Plateau during rice growing season.

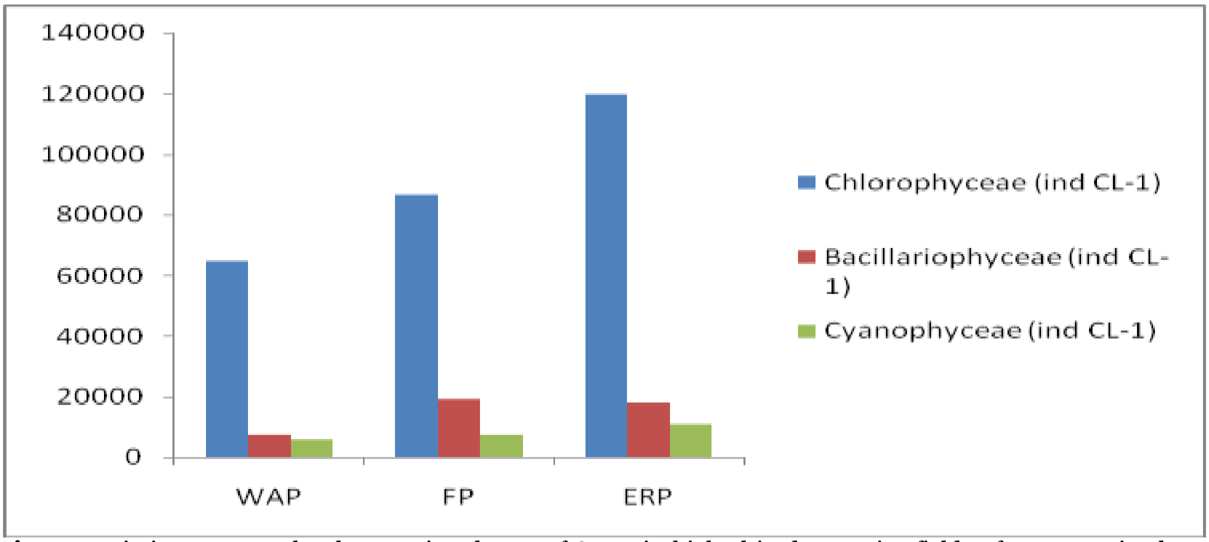

Fig. 5. Variations among the three major classes of SALF in high altitude wet rice fields of eastern Himalaya during rice growing season, 2013.

Conclusion

From the above study it can be concluded that in suspended forms, shallow rice wetlands have the highest dominance and diversity of Chlorophycean algae. But the concurrent presence of rice stems might have caused anchorage of various algal life forms reducing the counts of suspended population in the field water. So, it may be considered that the less diversity of Bacillariophyceae compared to Chlorophyceae among SALF probably resulted because of available additional surface area leading to spontaneous assemblages on the submerged portion of rice stems.

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