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Soil Quality Indicators and Microbial Development in Organic and Conventionally Farmed Paddy Wetlands Ecosystem in Kerala – India

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Abstract- Increasing global concerns about impacts of toxic chemicals, energy crisis and environmental protection, it is becoming more important to rely on local abundant agricultural bio resources than on chemical fertilizer. Understanding the effects of organic farming on the soil quality parameters, such as microbial activity and soil nutrient content, is of central importance to concepts of sustainability. Investigation were done on the quantity, type and application of organic amendments on temporal dynamics of paddy soil organic carbon (SOC), soil total nitrogen (STN) and soil microbial biomass (SMB). The study was conducted in a paddy wetlands of Padayatti in Erumayur panchayat, Palakkad, Kerala as part of the "Agro-Biodiversity Enhancement Programme" by Kerala State Biodiversity Board, to promote organic farming in the state. The data collected on the soil chemical and microbial parameters from selected organic farming stations (St. 1-3) in comparison to chemical fertilizer applied conventional stations (St. 4) from July 2009 to October 2010 formed the basis of this paper. In the present study it was observed that soil in Padayetti under organic cultivation was able to maintain marginally increased concentration of total soil organic carbon (SOC), soil organic matter (SOM), total nitrogen (TN) and soil microbial biomass as compared to the conventional fertilizer systems. Even though considerable variation could be observed in the organic and conventional fields in the context of soil chemical and biological parameters, however they were not very much pronounced. The average soil organic carbon value ranged from 0.379 to 1.26% whereas soil total nitrogen was in the range of 0.739 to 0.85%. Study stations with organic amendments showed enriched microbial biomass and nutrient availability than fertilizer applied fields. The heterotrophic microbial count showed an average highest value of 20x 10^6 cfu/g soils in organic station, whereas was $90x10^4$ cfu/g soils in fertilizer applied station. Therefore this study recommends long term application of organic inputs for restoring the native soil properties and health.

Index Terms- Organic farming, Sustainable agriculture, Soil Organic Carbon (SOC), Soil Total Nitrogen (STN), Soil Microbial biomass (SMB).

I. INTRODUCTION

With increasing global concerns over impacts of toxic chemicals, energy crisis and environmental protection, it is becoming more alarming to rely on local abundant agricultural bio resources than on chemical fertilizers. Recent studies have focused on re-considering organic fertilization practices to enhance soil organic input, fostering agricultural sustainability by promoting soil microbial biomass and activity. Conventional agro ecosystems have been characterized by high input of chemical fertilizer, leading to deterioration of soil quality due to reductions in soil organic matter and nutrients (Wu, 2009). Organic agricultural system relies on traditional practices like crop rotation, green manure, compost, and biological pest control, excluding or strictly limiting the use of synthetic fertilizers and synthetic pesticides, plant growth regulators, livestock feed additives, and genetically modified organism to maintain soil productivity.

Studies in comparison with conventional agriculture systems reveals that organically farmed soils showed improved soil quality with higher microbiological activity, higher pH, organic C, N mineralization potential, soil micro-organisms (30-40 %), and higher biological activity (30-100 %). Nitrate leaching rates on organic farms were shown to be significantly lower (40-64 %) and energy use to be more efficient (30-50 %) on a per hectare basis (FAO, 2002). Studies conducted between 1988-2001, comparing conventional and organic agricultural practices in both the US and UK have repeatedly showed higher levels of wild biological diversity (birds, arthropods, weedy vegetation and soil organisms) in organically managed farms (Witter and Kanal, 1998; FAO, 2002).

Soil quality in paddy wetlands depends on a large number of physical, chemical and biological soil properties, and its characterization requires the selection of indicators most sensitive to changes in management practices (Elliott, 1994). A better understanding on temporal and spatial variability of SOC, STN, microbial biomass and related factors is important for improving sustainable land use management (McGrath and Zhang, 2003) and providing a valuable base against which subsequent and future measurements can be evaluated. The soil chemical characteristics also play an important factor that determines as well as contributes to the abundance of organisms and productivity of the system. Therefore this study is unique in the Indian context where investigation were done on comparing organic and conventional farming type on temporal dynamics of paddy SOC, STN and microbial biomass in the rice cropping system of Palakkad Kerala.

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II. Materials and Methods

Study Area

The study was carried out from July 2009 to October 2010 in a tropical paddy wetland ecosystem located in Padayatti Village, Palakkad Dist. (10º41'137" N, 76º32'839" E), Kerala, India (Fig.1) situated at an altitude of 86 m above msl and has a tropical wet and dry climate with seasonally excessive rainfall and hot summer. The annual farming system consisted of early rice (July to September), late rice (November to January) and followed by summer fallow. The seeds commonly employed for cultivation were Navara, Aishwarya, Jothi, JST, 1001.

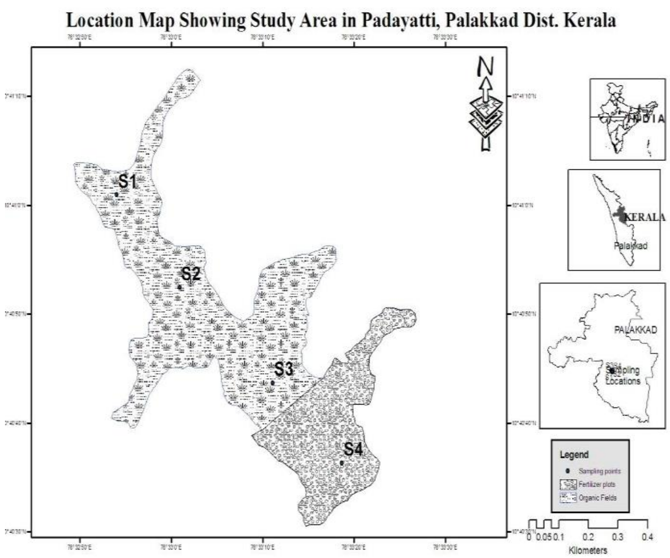

Fig. 1 Location map showing paddy wetlands of Padayatti, Palakkad

Organic and Conventional paddy Cultivation

Organic fertilization practices were introduced in the area as a part of a pilot project "Agro-Biodiversity Enhancement Programme" by the state government of Kerala –India, to promote organic farming. The total paddy wetland covers an area of 161.6 ha which was demarcated in to four stations. Station1 to 3 was under organic paddy cultivation, whereas station 4 was under cultivation using chemical fertilizers (Table 1).The organic farming was based on vermicomposting, leaf decoctions, and "Panchagavaya (Kumar et al., 2011). The vermicompost was applied at rate of 1tonne/acre, indigenously developed by the farmers of Padayatti, Palakkad. Whereas conventional farmers in Padayatti area were cultivating paddy making use of chemical fertilizers which was followed for decades.

Physio-Chemical Analysis of Soil

The soil samples were collected using a standard corer of 5 cm diameter and 40 cm in length. The sediment pH was measured using a Systronics make pH meter, NO.MK VI, whereas Eh was measured using Systronics make Eh meter, No.318. Total nitrogen was estimated by automated Kjeldahl digestion method (Jackson, 1973). Soil organic carbon (SOC) is determined using multi N/C 2100S Analytikjena TOC analyser. The organic matter was derived from organic carbon values (El-Wakeel and Riley, 1957), whereas the energy content was obtained from organic matter using an equivalent of 21.6 J/mg dry weights (Barnes, 1959). The microbial biomass, mainly the heterotrophic and total counts were also determined (Brown, 2001; APHA, 2005). The univariate & multivariate analysis were done by statistical software's SPSS version 16.

Table 1 Details on study stations in Padayatti wetland, Palakkad

Station	***Coordinates***	***Manure applications***	**Area (in acres)**
1. Organic	10° 41'057" N 76° 32'829" E	Vermicompost, *Panchagavaya*, Organic pest repellents etc	0.60
2. Organic	10° 41'085" N 76° 32' 856" E	Vermicompost, *Panchagavaya*, Organic pest repellents etc.	1.30
3. Organic	10° 41'127" N 76° 32'882" E	Vermicompost, *Panchagavaya*, Organic pest repellents etc	1.30
4.Chemical fertilizer	10° 40' 902" N 76° 32'777" E	Chemical manures like factomphose,Urea, ammonium sulphate, sulphur-phosphate & Chemical pesticides	0.40

III. Results and Discussion

Soil temperature

Significant difference in soil temperature was not observed between organic and conventional stations where highest temperature was observed in March 2010 with an average value of 34°C and lowest temperature of 21.6°C in December 2009 (Fig.2).

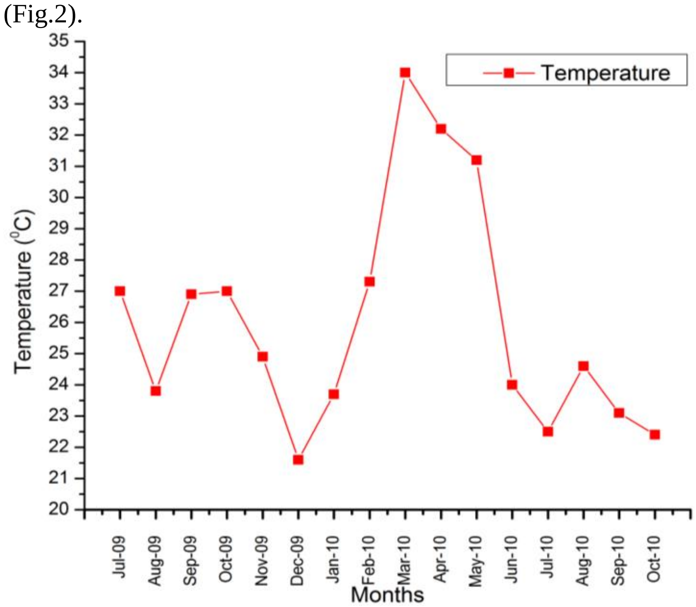

Fig.2 Monthly variation of temperature (◦c) in selected stations of Padayatti wetland, Palakkad 2009-2010.

Soil pH and Oxidation Reduction Potential (Eh)

In the present study, the average pH values were found marginally higher in organic amended stations as compared to conventional fertilizer stations. In St.1 an average pH value of 6.22 ± 0.55 was observed. pH showed a lowest value of 5.25 in March 2010 and a highest value of 7.1 in February 2010, with a coefficient of variation (CV %) of 8.67%. The characteristic pH values showed that, pH was acidic to neutral in St.1. In St.2 soil pH showed an acidic nature, with an average value of 5.94 ± 0.61 with a highest value of 6.8 in February 2010 and a lowest value of 3.81 in September 2009, having a coefficient of variation of 7.84%. In St. 3, pH values showed an average value of 6.11 ± 0.59, with a lowest value of 5.29 in November 2009 and a highest value of 7.3 in February 2010, with a coefficient of variation of 8.13%. St.4 showed an average value of 6.02 ± 0.38 with highest value of 6.9 in February 2010 and an acidic value of 5.51 in March 2010 (CV = 8.84%).

Seasonally, wide variation in pH was observed in the four stations. An average value of 5.91 ± 0.51 was observed in monsoon 2009, 6.44 ± 0.51 in pre monsoon, 6.036 ± 0.49 during post monsoon 2009 and 6.12 ± 0.54 in monsoon 2010 respectively. The ANOVA of soil pH showed an overall significance at 1% level (F = 9.873). The pH values were mostly acidic in nature during March, May, July and August 2010 in both organic as well as fertilizer farming stations. The rise in pH could be attributed to long-term changes in soil pH that occur as a result of displacing cations or adding sources of acidity such as H^+ and Al^{3+} on the cation exchange complex of soils as reported by Tisdale et al., (1993).

Seasonally the Eh values showed a similar trend in all stations. During the study period a reducing trend in Eh was observed in all seasons except pre monsoon (Fig.4). Dynamic changes in hydrological pattern greatly influenced the oxidation reduction conditions in the system. Oxidation-reduction potential is the measure of electron activity of the soil and is one of the most important electrochemical properties of the soil affected by the dynamic changes, when wetlands are subjected to hydrological fluctuations. Station wise analysis of Eh showed a similar trend in all stations depending on the hydrological pattern. During the study a reducing trend was observed during the water logged months in July, August, September, and October 2010 whereas an oxidative nature was observed during the dry months of November, December, January, and February 2010. The oxidation reduction potential showed a negative trend in st.1 having an average of -92.46 ± 129 mv with a lowest value of -336 mv in September 2010 and -102 mv in April 2010. St.2 also showed an average value of -92.62 ± 148 mv with the lowest value of -339 in the month of September 2010 and a highest value of 105 in May 2010. Average Eh value of -59.9 ± 123.9 mv was observed in st.3 with a minimum value of -298 mv in August 2010 and maximum value of 126 in May 2010. St.4 also showed a negative trend in Eh with an average value of -85 ± 101.3 mv, having a lowest value of -227mv and a highest value of 64 mv in April 2010.

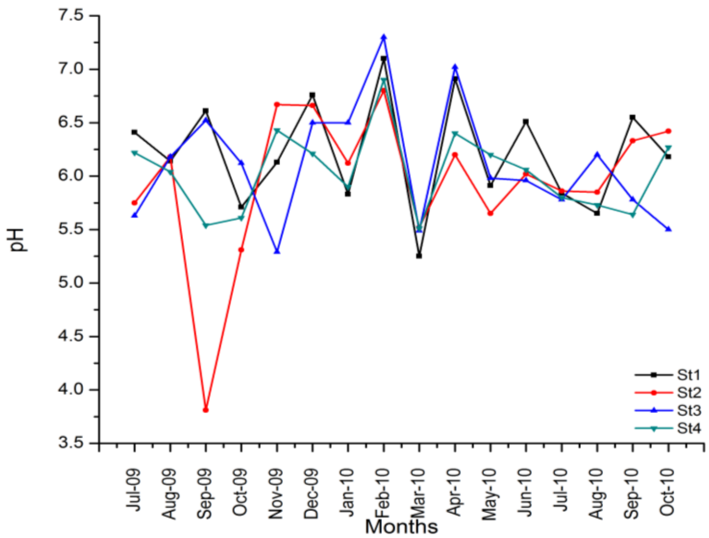

Fig.3 Monthly variation of pH in selected stations of Padayatti wetland, Palakkad during 2009-2010.

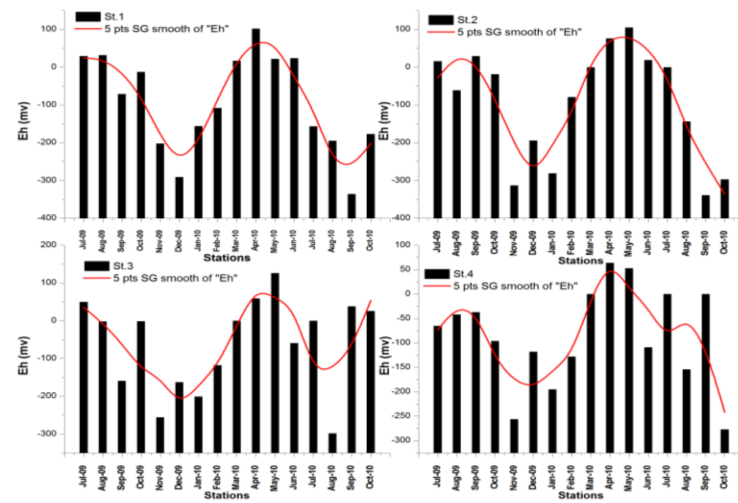

Fig.4 Monthly distribution of Eh (MV) in selected stations of Padayatti wetland, Palakkad, during 2009- 2010

Soil Organic Carbon, Organic Matter and Energy Content

Soil organic carbon is one of the most important terrestrial pools for carbon storage. It is estimated that the paddy wetland ecosystems on the earth have a total carbon stock of about 20–25% of the total stock in terrestrial soils and are considered to play an important role in global carbon cycling (Lal, 2002). Seasonally wide variation in organic carbon was observed in the four stations. An annual increasing trend in organic carbon (%) was observed in St.1 and 3 whereas St.2 and St.4 showed a decline in its concentration. In st.1 and st.3 maximum concentration of organic carbon were observed during the monsoon 2010, st.2 its highest concentration in pre monsoon whereas st.4 it was highest concentration in monsoon 2009. During the present study organic carbon showed an average of 0.714 % in the four stations. Station wise analysis showed an average value of 0.7196% in st.1 having a CV value of 34.04%, with a maximum value of 1.1% in June 2010 and a lowest value of 0.379% in February 2010. In st.2, organic carbon showed an average value of 0.786% with a maximum value of 1.26% in

December 2010 and a lowest value of 0.408 % in January 2010 having a CV value of 34.1%. In st.3 organic carbon depicted an average value of 0.69 % (CV = 44.22%) with a peak value of 1.2% in November 2010 and a lowest of 0.83% in January 2010. St. 4 showed an average value of 0.663 % with a maximum value of 1.29% in January 2009 and 0.419 % in April 2010 (CV = 31.84%) (Fig.5). Soil organic carbon showed an increased availability in soil during the months of April 2010 to August 2010. Mean results showed that st.3 had the highest organic matter with 0.769%. Studies comparing soils of organic and conventionally managed farming systems it was reported that, higher soil organic matter was reported in organic farming regions as compared to conventional methods (Reganold et al., 1987; Drinkwater et al., 1998). Seasonally the ANOVA of soil organic carbon showed that it was significant at 1% level (F = 12.187). Season wise, Duncan test was grouped into 3 subsets with a significant level of 1%.

Organic matter (Fig.6) and energy content (Fig.7) are reflective of organic carbon present in the system. During the study organic matter showed an average value of 1.613 ± 0.52% in st.1, 1.76 ± 0.62% in St.2, 0.688 ± 0.67% in st.3 and 1.486 ± 0.49 % in st.4 respectively. Seasonally wide variation in organic carbon was observed in the four stations.The ANOVA of soil organic matter showed a seasonal significance of 1% level (F = 0.871). Energy content also varied from 17.36 ± 13.19 j/g in st.1, 18.16 ± 11.25j/g in st.2, 19.77 ± 12.78j/g in st.3 and 16.25 ± 9.82 j/g in st.4.

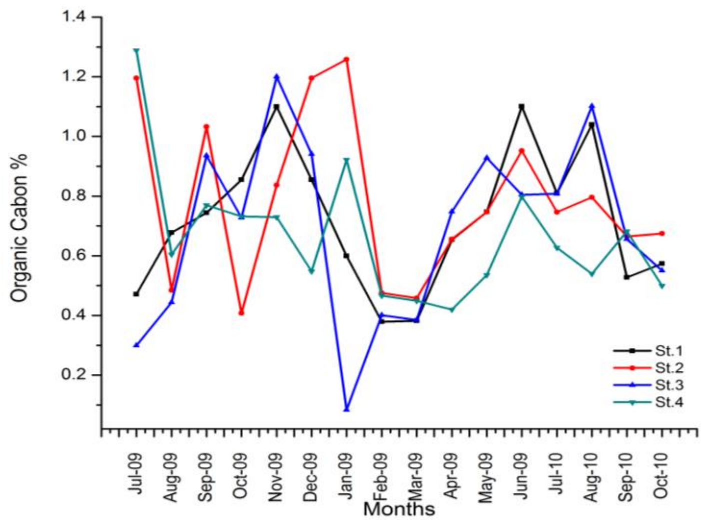

Fig.5 Monthly variation Soil organic carbon (%) among four stations in selected wetlands in Padayati, Palakkad during 2009-2010

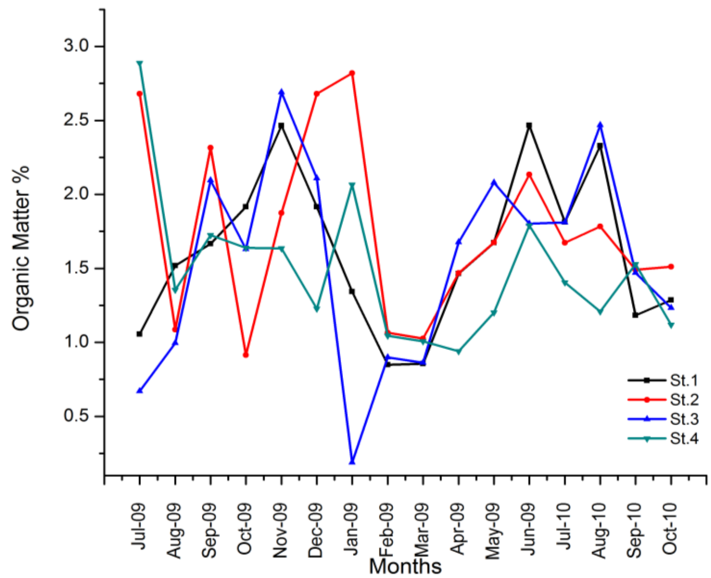

Fig.6 Variations of organic matter % in selected stations of padayati wetland Palakkad.

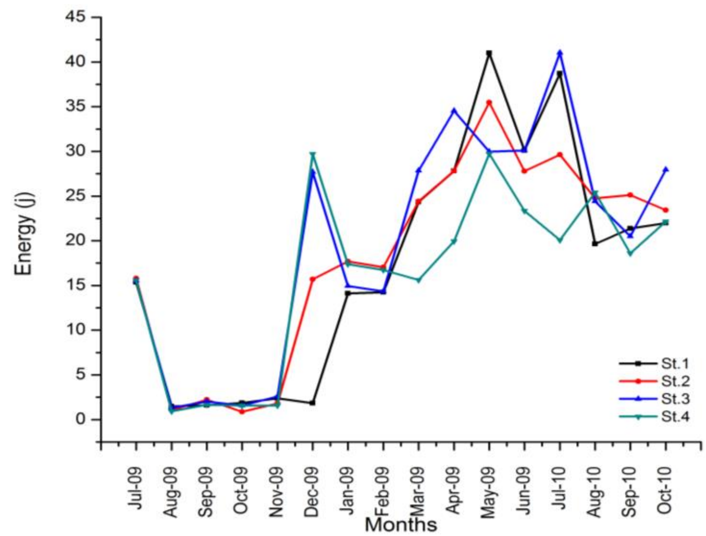

Fig.7 Distribution of energy content (J/g) in selected stations of Padayati wetland, Palakkad

Soil Total Nitrogen (STN)

Seasonally, in all the four stations monsoon and pre monsoon, periods showed highest concentrations of total nitrogen. The organic farming stations represented by st.1 to st.3 showed comparatively higher total nitrogen values as compared to the fertilizer amended station (St.4). However the overall examination of the data could not evolve any remarkable variability among the fertilizer or organic amended zones. Studies conducted by Gosling and Shepherd (2004) observed that the higher nitrogen content was related to organic fertilizer application. Total nitrogen has a significant correlation with soil organic matter and an enhancement in the total nitrogen content under organic fertilizer application were reported by Nguyen (1995) due to high loading of organic C and N in the organic materials. In an agricultural ecosystems soil total nitrogen (STN)

is a major determinant and indicators of soil fertility (Reeves, 1997). Thus a reduction in total nitrogen levels will result in decrease in soil fertility, soil nutrient supply and thus soil productivity (Gray and Morant, 2003). The station wise analysis of total nitrogen in the paddy wetlands of Padayatti depicted an average value of 0.739% in st.1, 0.768% in st.2, 0.85% in st.3 and 0.769% in st.4 respectively (Fig. 8). In st.1 an average value of 0.739±0.508% was observed. Total Nitrogen showed a lowest value of 0.265% in the month of January 2010 and a highest value of 1.825% in December 2009, with a coefficient of variation of 68.3%. In station 2 variations in soil total nitrogen showed an average value of 0.768 ± 0.779 %, with a lowest value of 0.096% in the month September 2010 and a highest value of 2.934% in November 2009, having a coefficient of variation of 101.41%. An average percentage value of 0.849 ± 0.779 in total nitrogen were observed in st.3, with a lowest reported value of 0.222% in January 2010 and a highest observed value of 2.78% in November 2009 (CV=91.38). St.4 the chemical fertilizer zone, showed an average value of 0.77 ± 0.556 % in STN, with a lowest observed value of 0.236% in the month May 2010 and a highest value of 2.01% in November 2009, with a coefficient of variation of 72.24%.
Seasonally wide variation in total nitrogen was observed in the four stations. A mean total nitrogen value of 1.02% was observed in monsoon 2009, 1.2% in pre monsoon 2009, 0.46% during post monsoon 2009 and 0.46% in monsoon 2010 in organic applied st.1to 3. Whereas an average value of 0.895% in monsoon 2009, 1.15 in post monsoon 2009, 0.44 during post monsoon 2009 and 0.59 in monsoon 2010 was observed in chemical fertilizer applied st.4. During the monsoon, st.1 showed a highest average value of 1.0569 % in 2009, whereas highest value of 1.4% was observed in st.2 during post monsoon. In the pre monsoon highest mean value of 0.503% was reported in st.3 and 0.59% in st.4 during monsoon. In all the stations the percentage variation of STN was low in both pre monsoon and monsoon whereas elevated concentrations were observed during post monsoon period. The ANOVA of soil total nitrogen showed an overall significance at 1% level (F = 14.182). In posthoc analysis, the 3 seasons were grouped into 3 subsets and were significance at 1% level. The correlation coefficient analysis of soil total nitrogen showed a positive correlation between organic carbon, organic matter significant at 1% level.

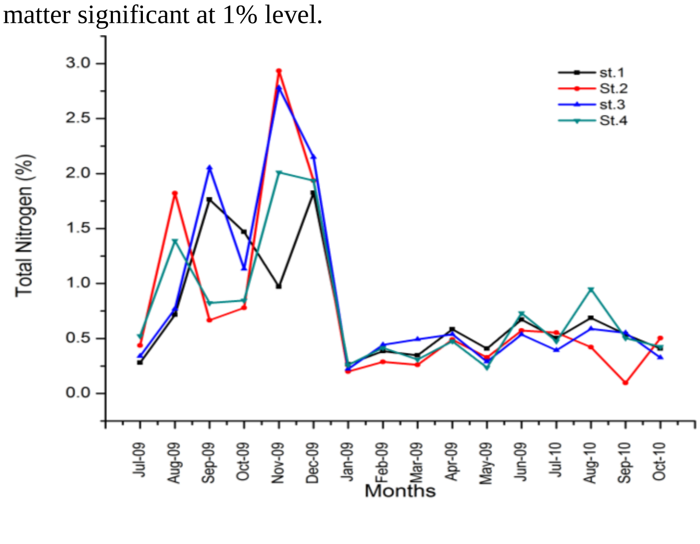

Fig.8 Monthly variation of soil total nitrogen(%) in selected stations of Padayatti wetland, Palakkad during 2009-2010.

Microbial Biomass

Comparative analysis of heterotrophic bacterial counts in organic and fertilizer fields revealed that heterotrophic count was significantly low in fertilizer stations as compared to the organic stations. Determination of soil microbial biomass is generally used as a rapid indicator of change in soil management which in turn affects the turnover of organic matter (Nannipieri et al., 1990). A relatively rapid response to organic amendments has been reported for microbial biomass carbon by several workers which suggest it could be a useful indicator in identifying positive effects of soil management (Fauci and Dick, 1994). Danish Bichel Committee, (Axelsen and Elmholt, 1998) reported that a transition to 100% organic farming in Denmark has increased the microbial biomass by 77% as a national average. Conversion to organic farming therefore provides opportunities for significantly increase the biological activity of the soil.
During the present study, station wise analysis of microbial biomass showed an average value of 17.52 x 10^5 in st.1, 12.95 x 10^5 in st.2, 16.76 x 10^5 in st.3 and 11.25 x 10^5 in st.4 respectively (Fig.9). In 2010 average highest value of 2413636 cfu/g soil was observed in st.1 whereas colony forming units of 1602727 cfu/g soil was observed in fertilizer stations. Monthly observation of the data showed that microbial count varied from 50000 cfu/g in March 2010 to 5350000 cfu/g in st.1; that from 9700 cfu/g in February 2010 to 6310000 cfu/g in September 2010 in st.2; that from 12000 cfu/g in February 2010 to 7410000 in st.3 and 0 in February 2010 to 2010000 in November 2010 in st.4.

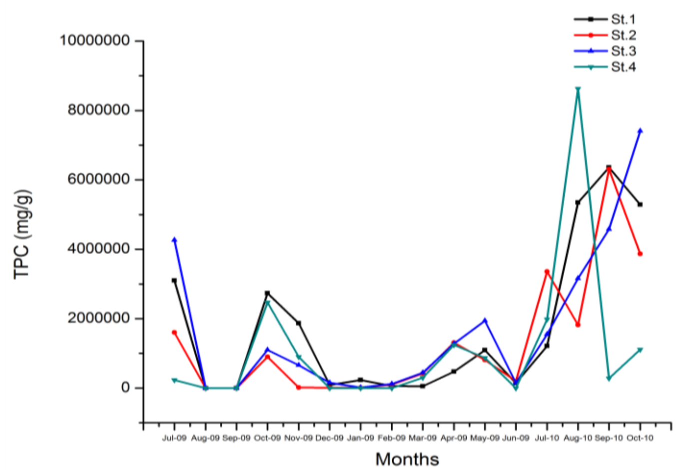

Fig.9 Monthly Variation heterotrophic bacterial count (cfu/g) among four station in selected wetlands in Padayetti, Palakkad during 2009-2010.

IV. CONCLUSION

The salient observations during the present study from February 2009 to October 2010 indicate that soil in Padayetti under organic cultivation was able to maintain marginally increased concentration of total soil organic carbon (SOC), soil organic matter (SOM), total nitrogen (TN) and soil microbial biomassas compared to the conventional fertilizer systems. Even though considerable variation could be observed in the organic and conventional fields in the context of soil chemical and biological parameters, however they were not very much pronounced. It may take considerable time for the organic elements mainly the microflora to become effective for regulating the quality of the soil. So this time delay could also be a factor for the low variability of different parameters in certain months of the study in different stations. Therefore, it is expected that, more pronounced variability of different parameters would be evolved through long term application of organic inputs by restoring the soil quality and health.

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