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Biodiversity Monitoring Study to Assess the Impact of a Comprehensive Organic Farming Practice namely Inhana Rational Farming (IRF) Technology on the Ecological Components of India's Largest Organic Tea Estate of Barak Valley, Assam, India

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Abstract

Biodiversity monitoring study was conducted in West Jalinga Tea Estate for the evaluation of the management impact on the different ecological components of the plantations viz. soil, water and bird diversity. The tea garden switched over to organic cultivation through the adoption of Inhana Rational Farming (IRF) Technology in 2001–02. Evaluation of soil quality components indicated improvement in soil health as compared to the conventional tea estates in the same agro-climatic zone. Especially enhancement of soil microbial population might be due to regular application of the microbial rich Novcom compost, which on the other hand rendered positive influence on the other soil quality parameters. Water quality in terms of both physicochemical parameters and macro invertebrate diversity indicates improvement of stream water quality within the tea estate. The different ecological indices like Species Richness Index, Shannon-Wiener Diversity Index and Rapid Biological Protocol III that measure water quality; also indicated significant improvement in water quality of the streams flowing through West Jalinga Tea estates when compared with the conventional tea estates. Bird diversity indices showed richness of species and population in the plantation which indirectly reflects an overall improvement of the ecological environment. This improvement was probably due to the stoppage of synthetic agro chemicals and simultaneous adoption of a comprehensive organic package of practice.

Keywords: *Inhana Rational Farming Technology, soil microbial population, water quality, species richness, bird diversity.*

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INTRODUCTION

Agriculture is a system which cannot survive alone without the support of the surrounding natural ecosystem and its biodiversity. These components although often underappreciated; are important for crop production for innumerable reasons including pollination, biological pest control, maintenance of soil structure and fertility, nutrient cycling and hydrological services [1]. But ironically, it is the modern agriculture that has become the single largest cause for the depression of biodiversity. Modern agricultural management practices had greatly influenced the potential for agricultural 'disservices', including loss of habitat for conserving biodiversity, nutrient runoff, sedimentation of waterways, and pesticide poisoning of humans and non-target species [2]. However, there is still a scope for wiping off the tag of 'anathema to conservation' through appropriate management practices [1].

Organic farming has been suggested to enhance biodiversity in agricultural landscapes. It emphasizes on management practices that promote biodiversity and soil quality towards maintenance of a sustainable agricultural system [3]. So far, organic farming seems to have enhanced not only the species richness and abundance of many flora and fauna, but also the overall soil fertility and productivity as reported by many workers [4–7].

Moreover, a true organic method invariably brings a noteworthy change in the surrounding ecosystem. The intensity and speed of this development indicates the harmony of this farming method with the interrelated mechanism of various components of ecosystem. When any organic practice is based on the agricultural science and attends the root cause of the problems by mitigating the underlying and contributory factors, then enhancement of biodiversity becomes an obvious outcome. Inhana Rational Farming (IRF) Technology is a concept of organic farming that explains the science, and interprets the synergism, cohesion and interrelatedness of all components of the eco-system in the restoration and rejuvenation of the soil system as well as reactivation of the plant physiology [8–11]. An ecological monitoring study was done to assess the impact of IRF Technology on the different ecological components, which contributed towards the richness of biodiversity.

MATERIALS AND METHODS

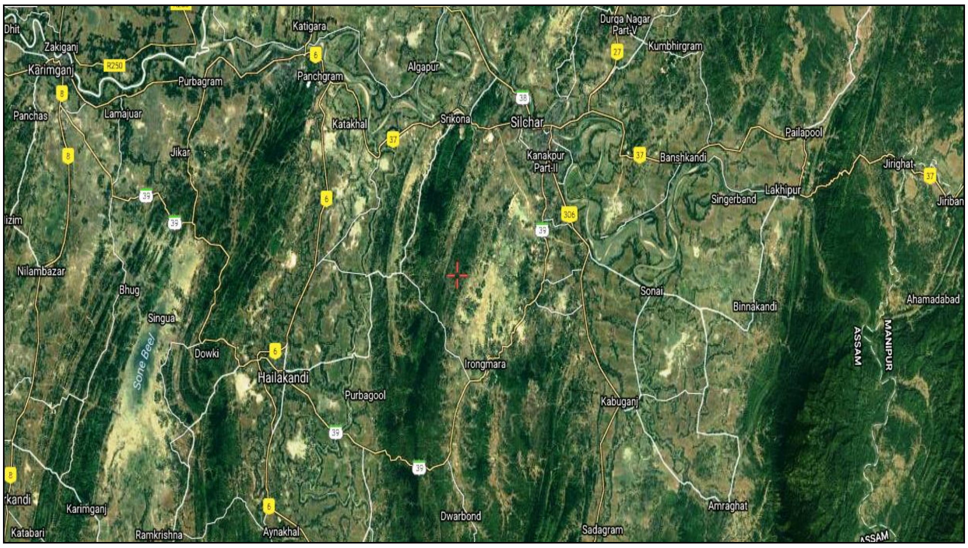
Inhana Rational Farming Technology, a comprehensive organic farming package of practice was introduced in 2001–02 in West Jalinga Tea Estate, Cachar district, Assam, India (Pic. 1); to switch over from the conventional chemical practice to scientific organic farming.

Three years post adoption of IRF organic package, a biodiversity monitoring study was undertaken in 2004–05 by the Department of Ecology, Assam University to assess the comparative impact of organic system *vis-a-vis* the conventional farming practice on the ecology of this agro-climatic zone.

Inhana Rational Farming Technology

Inhana Rational Farming (IRF) Technology is a Comprehensive Organic ‘Package of Practice’ aimed towards farming rationally, in harmony with nature. The practice nurtures the crop, right from the seed till its harvesting stage. This technology has been developed by an Indian scientist, Dr. P. Das Biswas, (Picture 2) who has been associated with the organic research activities for over 20 years; and this technology has been the fruit of his toiling.

The Technology focuses towards rebuilding the interrelated and integrated relationships of the soil, plant and ecology that go on to ensure ‘Sustainable Agriculture’. It focuses on soil quality restoration and activation of plant physiology that leads towards ‘Healthy Plants’. The idea is to tap the inherent potentials of the plant towards nutrient utilization as well as immunity against pest/disease infection [12].



Picture 1: *Satellite Image of West Jalinga Tea Estate, Assam, India.*

Picture 2: *Dr. P. Das Biswas, Developer of Inhana Rational Farming (IRF) Technology.*

Management Practice under IRF Technology

Organic crop management under IRF Technology can be broadly divided into 10 components:

SWOT Study

SWOT study and soil resource mapping to identify potential and problematic areas, for judicious application of organic soil inputs as well as to increase the intensity of plant management as per requirement.

Soil Health Management

Application of on-farm produced Novcom compost (micro flora population in the order of 10^{16} c.f.u. per g compost) @ 3 ton ha^{-1} and different on-farm concoctions *viz*. energized cow dung slurry, compost tea etc. towards soil microbial rejuvenation.

Plant Health Management

Application of different potentized and energized botanical solutions in a scheduled manner for bringing about harmonized plant growth through stimulation of different plant biochemical functions *viz.* photosynthesis, respiration, transpiration etc. as well as better metabolism. The solutions also provide necessary energy to the plants for biotic and abiotic stress management.

Drought Management

Most of the area in West Jalinga Tea estate is without irrigation and due to its undulating topography; it is difficult to bring the entire area under the cover of irrigation. Specific drought management practice was adopted under IRF to minimize water stress in the plant system through energization of specific plant functioning.

Hail Management

Specific hail management package is adopted towards recovery from shock and physical damage; minimize risk of disease and secondary pest infestation and towards initiation of fresh growth.

Pest Management

Principally pest management under IRF Technology is done through 'Plant Health Management'. The approach works towards bringing about a paucity of pest nutritional components like free amino acids, reducing sugars etc. in the cell sap of plant; so that they become unsusceptible to pest attack. The second focus points are to develop the structural and biochemical defences of the plant to ward of disease causing pathogens. The third approach is to develop an effective soil microbial barrier against soil pathogens. Till the time the Plant System is fully activated some organic inputs like sulphur (for mites), crude oils like neem, karanj etc. (for sucking/chewing insect/pest) is utilized to keep the pest population under economic threshold limits. However, cidal approach is avoided as much as possible, in order to restore the Natures' Balance.

Termite Management

Termite infestation was checked through adoption of cultural practice combined with an energized botanical solution under IRF technology which naturally discourages the build-up of the termite population. Also the overall development an environment for the co-existence of the plant–soil–macro/micro flora and fauna also helps to sort out the termite problem.

Disease Management

Application of the IRF Disease Management Schedule provides the necessary energy for better biochemical reactions and enhanced silicon uptake that strengthen the structural and biochemical defence system of plants, against pathogens.

Weed Management

Manual weeding, cultivation of leguminous plants and cover cropping for weed control.

Nursery and Young Tea Management

Inhana Rational Farming Technology has a complete package of practice for upbringing of nursery tea seedlings as well as new plantation towards development of climate resilient, healthy bushes with high yield potentials.

Physicochemical variables of soil such as texture, bulk density, porosity, water holding capacity, organic carbon, nitrate, phosphate, sodium, potassium; dissolved oxygen, free carbon dioxide, total alkalinity, nitrate, phosphate, DO, etc. were estimated using standard methods [13, 14]. Microbiological properties of soil such as density of fungi, actinomycetes, bacteria, phosphate-solubilizing microorganisms and microbial respiration were analyzed according to Dubey and Maheshwari [15].

Data Collection of Aquatic Species

Aquatic species were collected by kick method whereby the vegetation was disturbed and a circular net (mesh size: 60 μm) was dragged around the vegetation for a unit of time [16, 17]. Three such drags constituted a sample [18]. Collected insects were immediately sorted and preserved in 70% ethyl alcohol. They were later identified using an advanced microscope with the help of standard keys [19–25].

Methods for Bird Count

Variable width point count method along transect was used for sampling birds [26]. Transects were laid along tea plantations only. Point count method was adopted as an effective census technique because the stationary observer has a greater probability of detecting and hearing birds even if the birds are inside the bushes.

In each site mentioned in the study area above, five transects were established, and within transect five points were marked making a total of 25 points per site. The points within transects were spaced 200 m apart in order to avoid repetitive counting of same individuals during sampling. Hence, a total of 125 points were laid for the present study covering five study sites. In each point, observation of birds was made for 10 minutes; recording the number and identity of species seen or heard. Birds were scanned with the help of a binocular and identified using the standard field guide [27]. Sampling was conducted in the morning hours (05:00–9:00 hrs) in clear sunny days. Bird counts were repeated three times in each transect.

RESULTS AND DISCUSSION

Assessment of Soil Physicochemical Properties

According to generally held views acidity in soils has several sources, humus or organic matter, alumino-silicate clays, hydrous oxides of iron and aluminium, exchangeable aluminium, soluble salt and carbon dioxide. High acidic pH value of the soil also indicates the lesser presence of life forms and soil microorganisms. A pH value below 5.5 suggests the presence of appreciable amount of aluminium, whereas pH values around and below 5.0 are indicative of a high degree of aluminium saturation. The pH value of the soil of the organic Tea Estate also clearly shows that the status is better than the conventional tea estate in terms of aluminium saturation (Figure 1).

Electrical conductivity is the measurement of salt concentration in soil solution. High salt concentration in soil severely affects crop growth due to physiological water deficit on account of high osmotic potential at the root zone soil solution and specific ion effects. Excess concentration of specific ions in plant may lead to primary effects i.e. toxic effect on various physiological processes and nutritional imbalances or disorder. As an example high level of sulphate concentration in soil reduces uptake of calcium and increases the uptake of sodium, which cause cationic imbalance in plants. The high EC values of conventional Tea estate clearly indicate long-term application of chemical fertilizers, which may hamper plant growth as well as disturb the soil microbial environment (Figure 2).

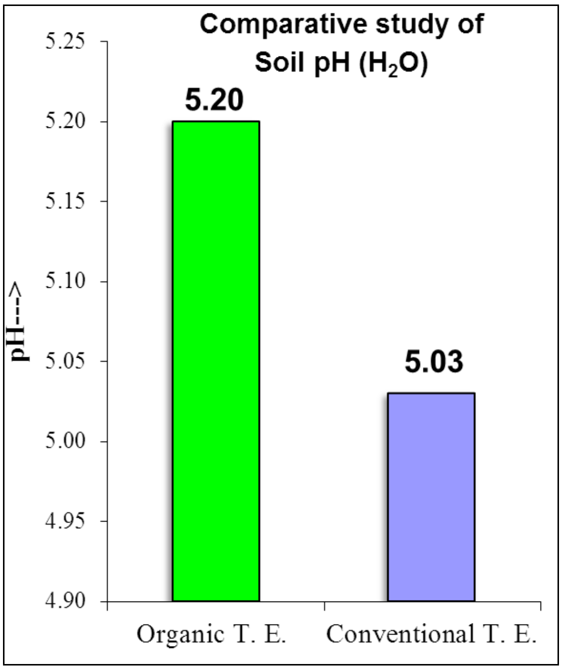


Fig. 1: *Comparative Soil pH Study.*

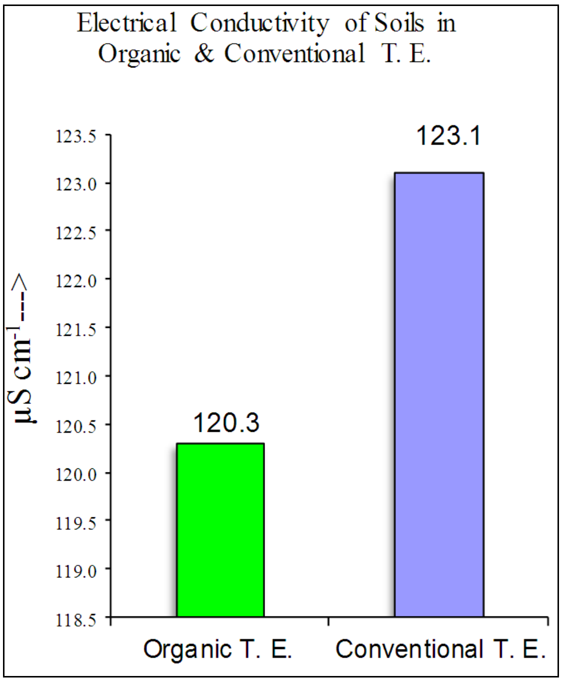


Fig. 2: *Comparative Soil Electrical Conductivity Study.*

Soil structure to a great extent determines the bulk density of a soil. As a rule, the higher the bulk density, the more compact is the soil, the more poorly defined are the structure, and the smaller the amount of pore space. This is quite frequently reflected in restricted plant growth as high bulk densities inhibits the emergence of the seedlings and also offers increased mechanical resistance to root penetration. The bulk density of the Conventional Tea Estate has been found 16 percent higher than that of the Organic Tea Estate (Picture 3). The lower bulk density clearly proves that organic farming practice has developed the textural class of the soil to a great extent.

Lower bulk density is always a favourable indication to the plant growth as high bulk density offers increased mechanical resistance to root penetration. They almost certainly influence the rate of oxygen diffusion into the soil pores and root respiration is directly related to a continuing and adequate supply of this gas. Pore space, of course, is occupied by air and water and the amount of one is inversely related to the amount of other. Under field conditions oxygen diffusion into the soil is determined largely by the moisture level of the soil, if bulk density is not a limiting factor. The development of soil indicates that application of Novcom compost (Picture 4) and the various botanical solutions used to energize the plant system have initiated the conversion in the soil structure within a very short period (Figure 3).

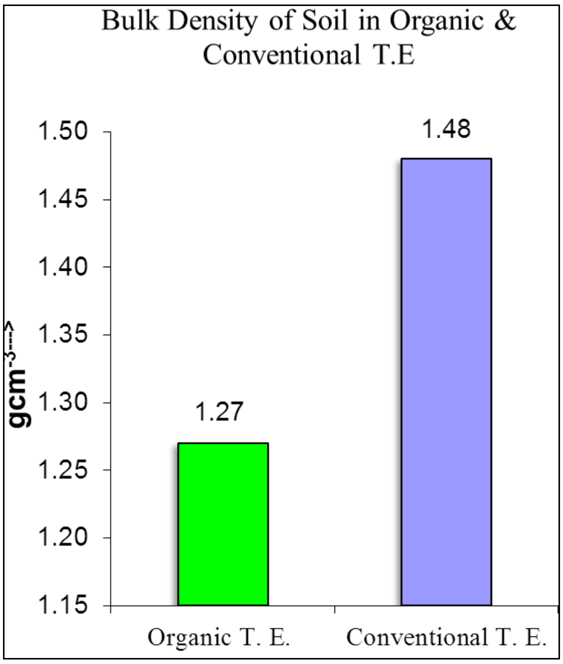


Fig. 3: *Comparative Study of Soil Bulk Density.*

Picture 3: *Landscape View of West Jalinga Tea Estate, World's 1st Carbon Neutral Tea Estate.*

Picture 4*: Novcom composting at West Jalinga Tea Estate.*

Organic carbon, which forms as a result of the decomposition of soil organic matter reflects the fertility status of the soil and also helps to restore the soil physical properties. Organic carbon greater than 0.75 suggests moderately high status and is an indication of a steady mineralization process.

However research suggest that continuous application of organic matter even up to a period of 20 years cannot bring about a significant increase in the soil organic carbon percentage. Henceforth it was concluded that organic matter conversion or organic carbon percent is an inherent soil mechanism and cannot be increased within a short period of time. The comparative study of conventional and organic tea estate showed 26.75 percent higher organic carbon status in the organic tea estate. This is perhaps due to better conversion of organic carbon from organic matter, which is totally governed by the soil microbial activity. This component, which is highly enhanced in an organic environment, enables a steady transformation process. The finding indicates the positive influence of Novcom compost and the other soil energization processes as adopted under Inhana Rational Farming Technology. In the conventional tea estate, on the other hand the regular input of chemical substances deactivates the microbial environment, which slows down the humification process thereby leading to the depletion of organic carbon content (Figure 4).

Water holding capacity of a soil depends upon soil textural class, its bulk density and pore space and up to a certain extent, on the organic matter status. In similar textured soil, bulk density and percent pore space can vary greatly depending upon the nature of cultural practices adopted, which influences the soil microbial environment. The soil microbial populations play a very important role in restoring the soil structure, which indirectly influences the soil bulk density. The water holding capacity of organic tea estate was found to about 3.4 percent higher than the conventional tea estate indicating greater pore space and subsequently lower bulk density, which is again reflective of enhanced microbial activity in the former soils (Figure 5).

Nitrate ions are formed as a result of decomposition of organic sources or transformation of inorganic compounds by different groups of microorganisms. In organic tea estate, microbial population is activated due to the restoration of a favourable soil environment as a result the natural cycle of NO_3^- transformation ensues and these nitrates are further rendered at specific exchange site for favourable plant uptake. Since these nitrates are from organic source, these are transformed by the microorganism with all desirable steps, where there is no risk of nitrate toxicity, no pollution of water bodies or life forms and finally constant support to the plant system for continuous productivity at a desired level. This is the clue behind how nitrate can be distributed into more uptake sites for better plant uptake, and lesser loss potentials.

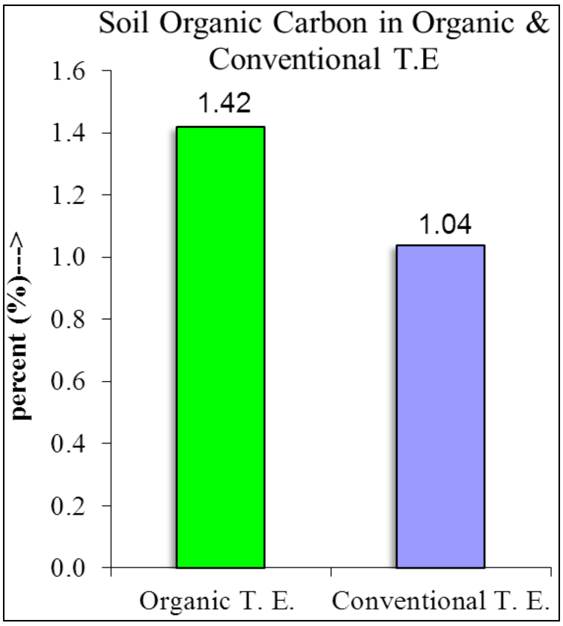


Fig. 4: *Comparative study of Soil Organic Carbon.*

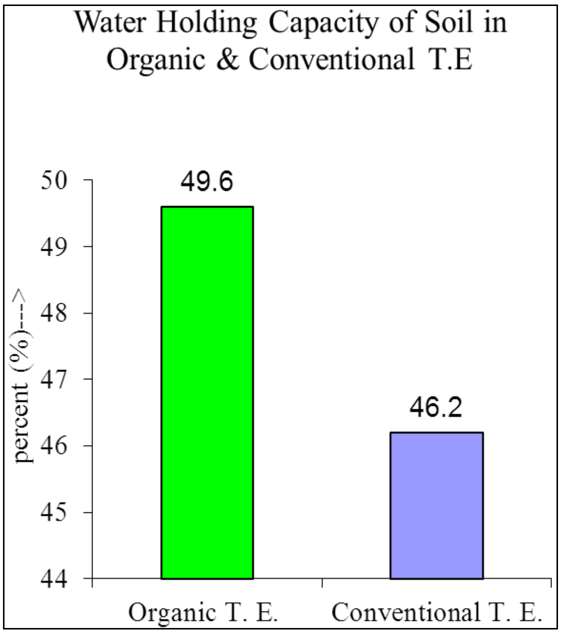


Fig. 5: *Comparative Study of Water Holding Capacity of Soil.*

Chemical fertilizers in large dozes and weedicides application kill and deactivate the soil microbial populations thereby hampering the natural nutrient transformation processes. As a result, the nitrate ions accumulate in the soil solution, where only a small portion is taken up by the plants and the rest remain in the soil solution and cause root toxicity before being leached out of the soil. This is phenomenon is reflected in the low nitrate content of the conventional tea estate soils. This must be confirmed by the water analysis because there should be less nitrate in the water and more nitrifying organisms in the soil respectively (Figure 6).

Among the various factors that control the availability of soil phosphorus, pH is the most important. At low pH phosphate is generally precipitated in the form of iron and aluminium phosphates, and remains unavailable for plant uptake. These precipitated phosphates can be rendered soluble by the phosphate solubilizing bacteria however in conventional soil the situation is aggravated by the fact that these microbes, which are already in a stressed out condition, stop functioning at low pH. In an organic environment on the other hand the soil is allowed to function normally and hence can act as a buffering medium. This creates an ideal environment for the microbes especially the phosphate solubilizing bacteria, which starts functioning efficiently resulting in increased availability; as indicated by the high phosphate values in the organic tea estate as compared to the conventional one. Phosphate is a slowly mobile element and is not flushed or leached out easily like many other soil elements and even in chemical farming it is applied as an organic source (Figure 7).

Hence, it can be presumed that in Jalinga Tea Estate phosphate availability will be maintained throughout the various growth phases, if this environment is maintained.

Assessment of Soil Microbial Properties

The soil environment is one of the most dynamic sites of biological interactions in nature and these mechanisms are mainly governed by the different microbial populations viz. bacteria, fungi, and actinomycetes; and their role is predefined by nature. However the most important factor is that these microbes proliferate and carry out their activities efficiently in the environment which nature has provided and together they control the equilibrium of soil-plant system. Five different agro-ecological system *viz.* organic tea estate, conventional tea estate, organic paddy field, forest and grassland were taken for the comparative study for the most authentic conclusion. In general the forests are considered to be the most ideal ecosystem for the rapid growth and proliferation of the different soil microbes. Since these soils are practically undisturbed hence the microbial populations in this system does not face any competition and can function normally, which ultimately leads to an enriched soil system. This can be substantiated by our findings in case of forest soils. In the paddy field the microbial density always remains higher because of the waterlogging situation for a short period. Hence, this system was also taken up for the study for effective comparison.

Fungal distribution is mainly determined by the availability of oxidizable carbonaceous substrates, which might be the obvious reason for their greater density in the organic paddy field. High fungal density in organic tea estates (Figure 8) is attributed to the higher pore space as previously discussed, allowing better oxygen flow in the soil as well as a high organic matter status that provide a conducive environment for microbial growth and proliferation. The fungal enrichment is soil of W. Jalinga tea estate has been recorded within just two years of adoption of IRF Technology. Such intense development within a short time span was probably contributed by the process of soil energization.

In a normal soil, actinomycetes form the major share of the microbial population; after bacteria. It is generally observed that these organisms show exponential growth and prolific activity under the availability of a ready source of organic matter. However they are very sensitive to fertilizer application and fertilizer induced pH decrease. Hence in the conventionally cultivated fields despite the huge availability of oxidizable carbonaceous substrates, low status of these microbes is observed. Microbial analysis reveals that the organic paddy field and organic tea estate soils have a fairly rich population of actinomycetes as compared to forest, grassland and the conventional tea estate soils. This is suggestive of the absence of toxic elements and qualitative enrichment of the soils, which has been perhaps achieved by the implementation of IRF Technology (Figure 9).

The maximum bacterial density is found in the region of fairly high moisture content and often, the optimum level for the activities of aerobic bacteria is at 50 to 75 percent moisture holding capacity. Bacterial density of the organic paddy field was highest closely followed by forest, whereas soils of conventional tea estate showed the lowest population.

The bacterial populations show suppressed activity under application of ammonium containing fertilizers due to the acidity generated through the microbial oxidation of ammonium to nitric acid. The comparatively higher bacterial population under the organic system is suggestive of the absence of toxic elements and enrichment of the soil system (Figure 10).

In the previous discussion attention was drawn towards the high values of available phosphate and the nitrifying bacteria in W. Jalinga Tea Estate as compared to the conventional one. Now at low or acidic pH majority phosphate in the soil is fixed in the form of iron and aluminium phosphates, which contradicts our former findings.

In the natural cycle the soil phosphate dynamics is mainly controlled by the phosphate solubilizing microorganisms. Hence, if the microbial efficiency of the soil can be restored, as is indicated by the above findings from the organic tea estate, it leads to efficient phosphate dynamics even in an acidic soil (Figure 11).

Microbial respiration, which indicates the functional efficiency of the soil microbes, was found to be significantly high in the organic tea estate even as compared to the forest soil; that is considered to be the most ideal environment for microbial proliferation and their efficiency. The higher response in W. Jalinga tea estate might be the result of the soil energization as bought about by the application of Novcom compost and various others on farm produced soil energizers (Figure 12). The study indicated that the organic tea estate soils have higher microbial density as compared to the conventional one. Since these organisms cannot tolerate the hostile environment created by the continuous addition of chemical inputs hence toxicity of the synthetic chemicals is immediately indicated by the severe depletion in microbial population and their stagnated activities.

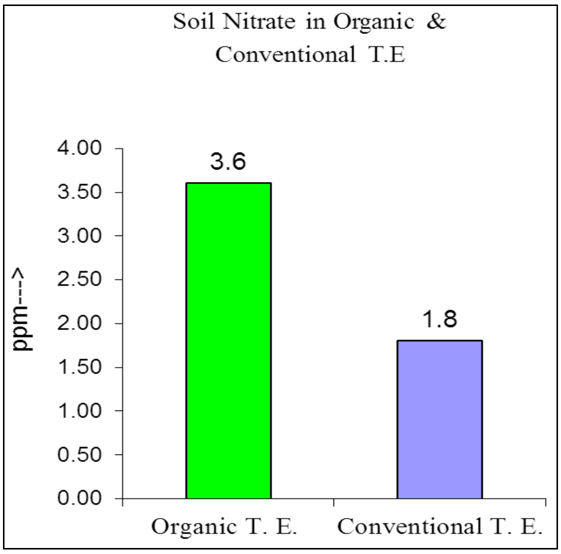


Fig. 6: *Comparative Study of Soil Nitrate.*

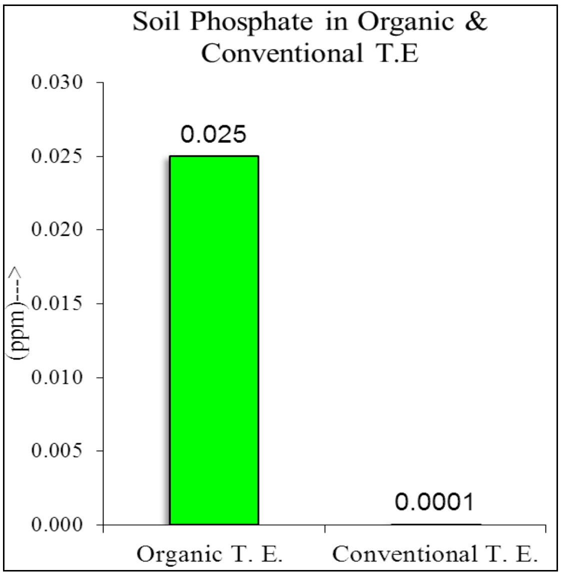


Fig. 7: *Comparative Study of Soil Available Phosphate.*

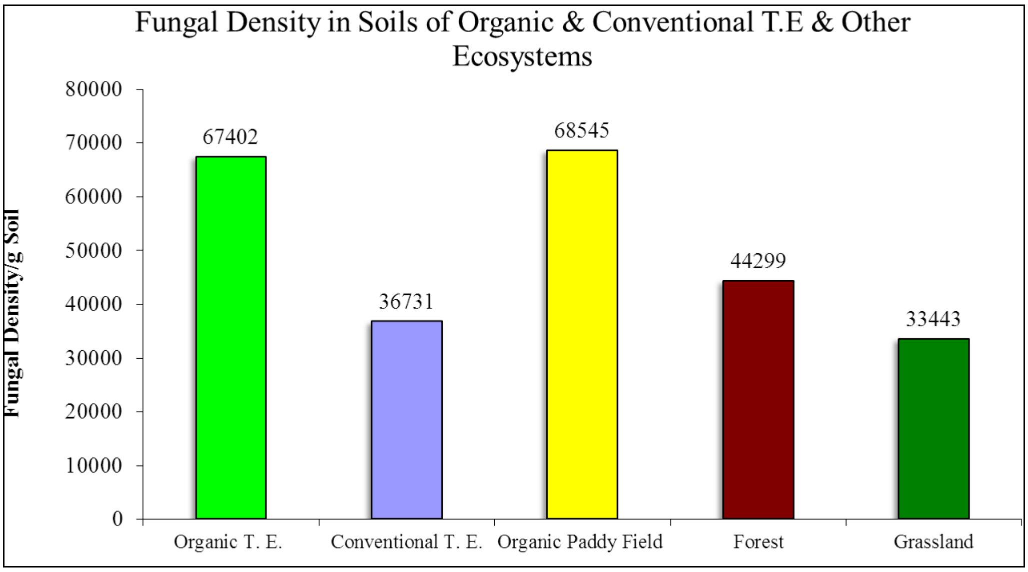


Fig. 8: *Comparative Study of Soil Fungal Density.*

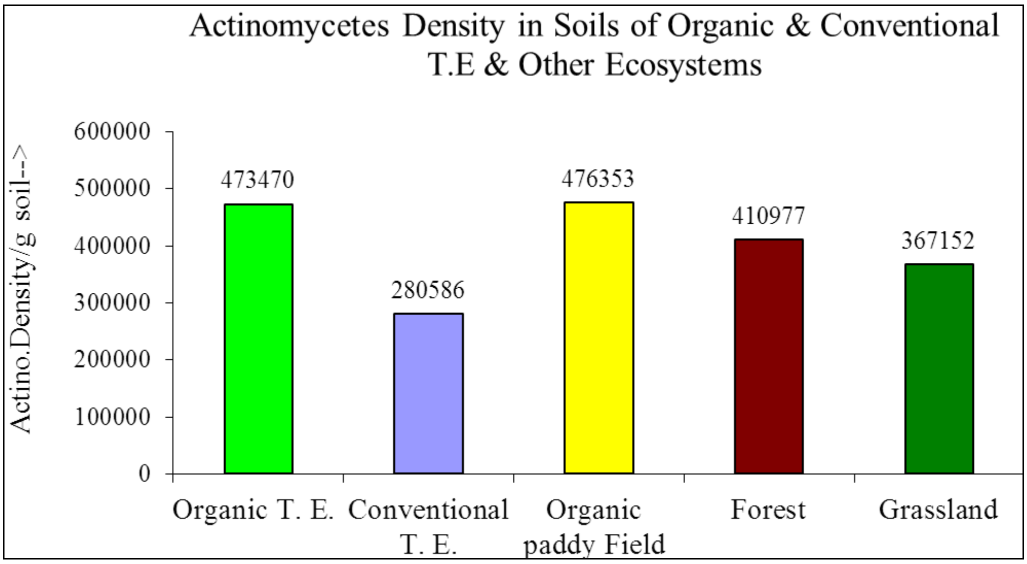


Fig. 9*: Comparative Study of Soil Actinomycetes Density.*

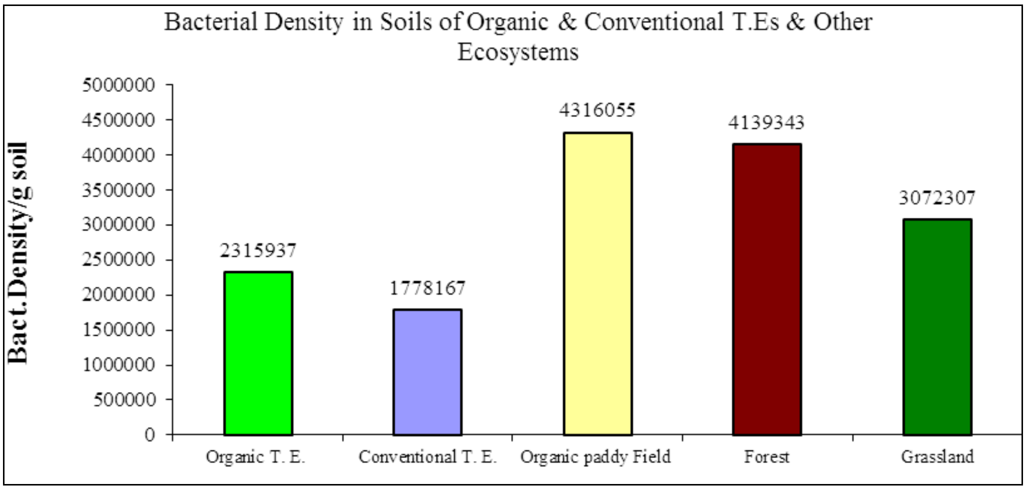


Fig. 10: *Comparative Study of Soil Bacterial Density.*

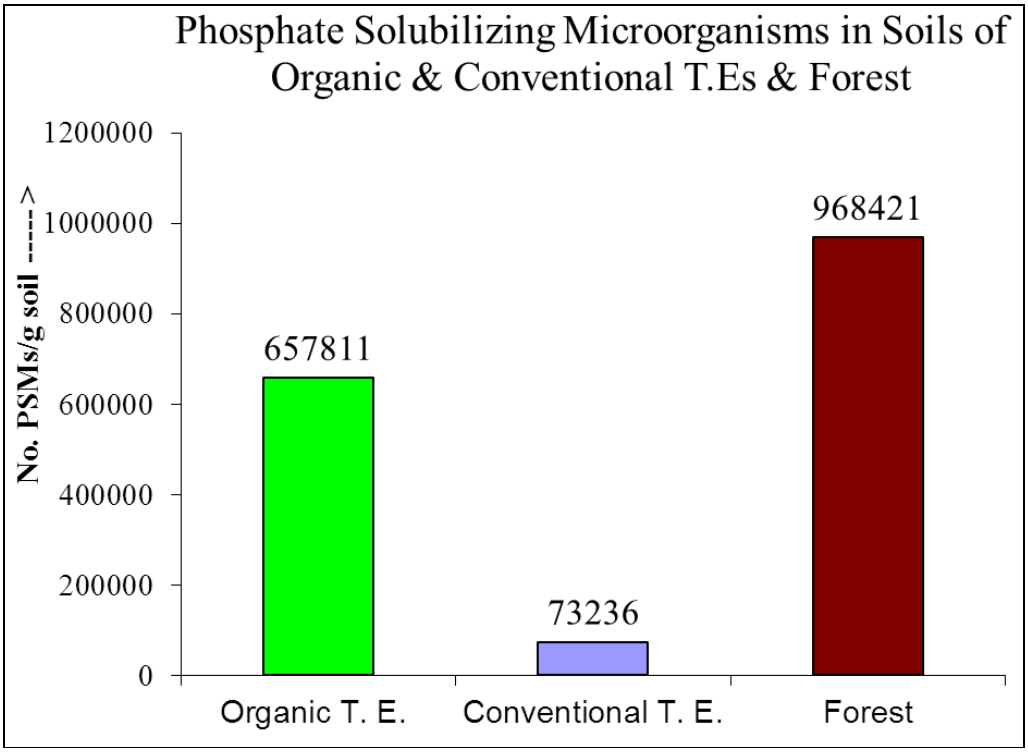


Fig. 11: *Comparative study of Phosphate Solubilizing Microorganisms in Soil.*

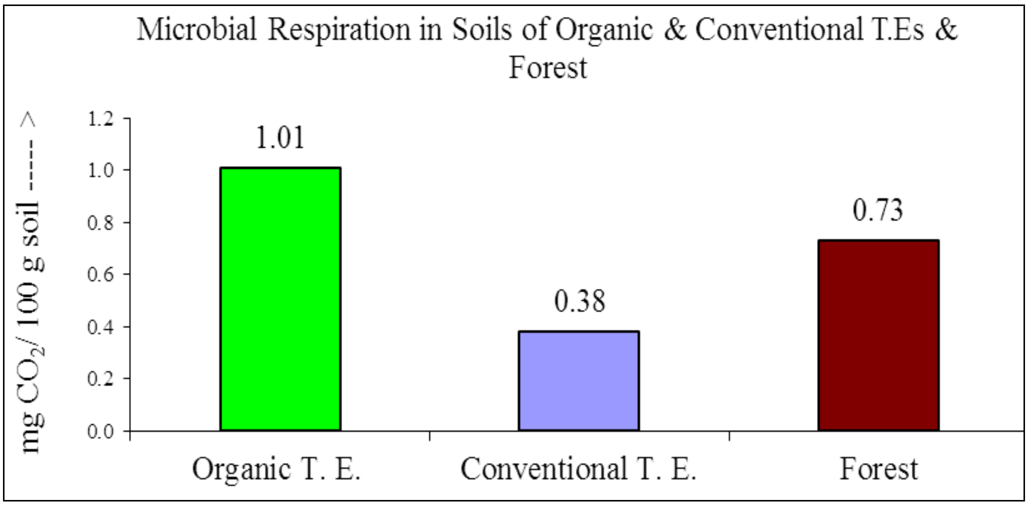


Fig. 12: *Comparative Study of Soil Microbial Respiration.*

This disturbs the natural equilibrium of soil-plant ecosystem, which is ultimately reflected by the deterioration of the soil quality and lower values of the qualitative indices. Moreover, soil microbial populations play a very critical role both in a direct and indirect manner in the entire ecosystem, environmental resistance and plant function. Hence higher microbial density along with the generation of specific genera clearly signifies that such development is possible in the speediest manner, if the right method is adopted.

Microbial Analysis of Novcom Compost

Generally compost is rated by its nutrient content more specifically the carbon and nitrogen content since the current scientific theory goes by the belief that plants need these nutrients from the soil and these must be regularly supplied into the soil. However in the present depleted state any ordinary compost, which are made for nutrient replenishment as a substitute for chemical fertilizers; cannot provide the desired results. An ideal exogenous soil inoculation is required which will not only enrich the soil organic matter status but also increase the soil exchange capacity, restore the soil physical properties and above all provide a favourable environment for restoration of the native microflora population. The effectiveness of such compost depends on the nature of degradation achieved during the composting process, which in turn is governed by various factors such as C:N ratio of the raw material, moisture, temperature, oxygen supply etc. Among these components, temperature is the single most important factor responsible for the end product quality. Such favourable conditions for speedy and effective biodegradation are achieved under Novcom composting method. The following graphs represent the variation in the microflora population of Novcom compost under varying conditions.

In an ideal composting process the generation of high temperature (65–70°C) during the first decomposition stage leads to rapid growth of the thermophillic bacteria and fungi, which hastens the biodegradation process during which the pathogenic microorganisms and weed seeds are destroyed. In the later stages when the temperature lowers down the actinomycetes population starts building up and cause the degradation of the celluloytic or lignolytic substances.

Comparative evaluation indicates high bacteria, fungi and actinomycetes density in the compost produced at the central composting unit as compared to the ones produced in the sections of the garden sectional. The finding remained constant irrespective of the type of raw material used *viz.*, water hyacinth which is considered to be raw material of choice (Figures 13–15). In the central composting unit the composting is carried out in total compliance of Novcom Composting Method and absolute precision is maintained in terms of methodological control. This results in high heat generation and simultaneous temperature rise in a rapid, intense and programmed manner, which results in the generation of a large microbial population as suggested by the microbial analyses of the central compost. However in the sectional compost such methodological control is not possible due to the convenience factor along with along with lack of control points, *viz*. moisture content, protection from rain etc. Hence, the biodegradation occurs in a slightly compromised manner, which substantiates the lower microbial status of the sectional compost.

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This can be corroborated by bacteria, fungus and actinomycetes population in the organic paddy field and Jalinga tea estate soils as compared to the value obtained in the conventional tea estate. High population of phosphate solubilizing bacteria and the comparable availability of phosphate in the organic tea estate soils is also in agreement with the above statement. Now the microbial population is known to control various physical processes viz. organic matter degradation, restoration of soil structure etc., as well as the soil nutrient dynamics, which again leads to an overall beneficial effect on the soil health. High organic carbon status, lower bulk density, high water holding capacity as well as the higher nitrate and phosphate content in the Jalinga Tea Estate soils is suggestive of a better soil quality, which have been achieved primarily through the regular application of Novcom compost.

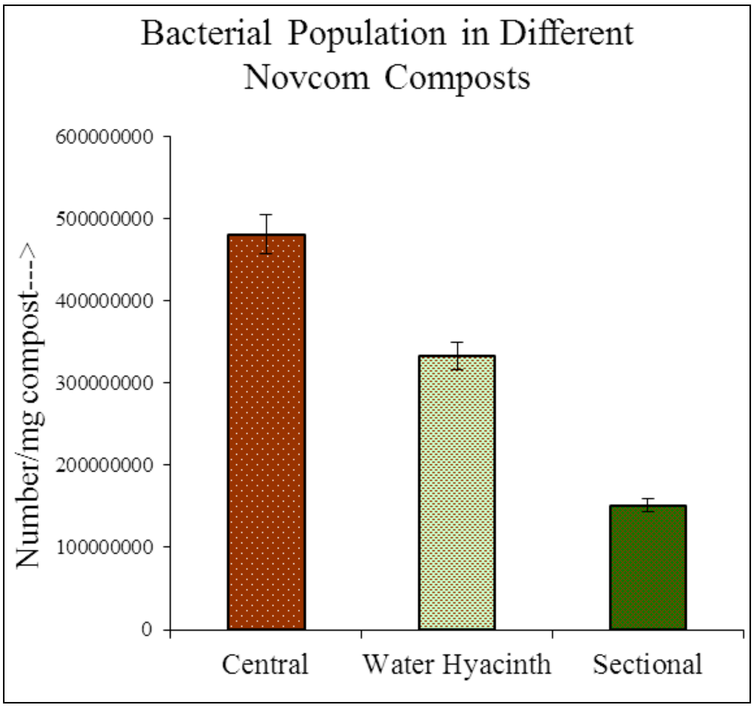


Fig. 13*: Comparative Study of Bacterial Population of Different Novcom Compost.*

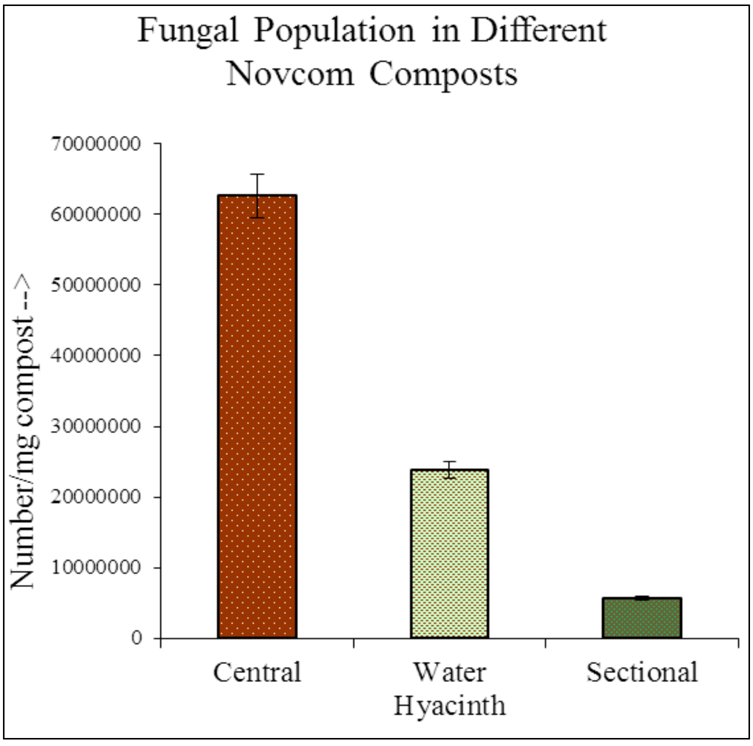


Fig. 14: *Comparative Study of Fungal Population of Different Novcom Compost.*

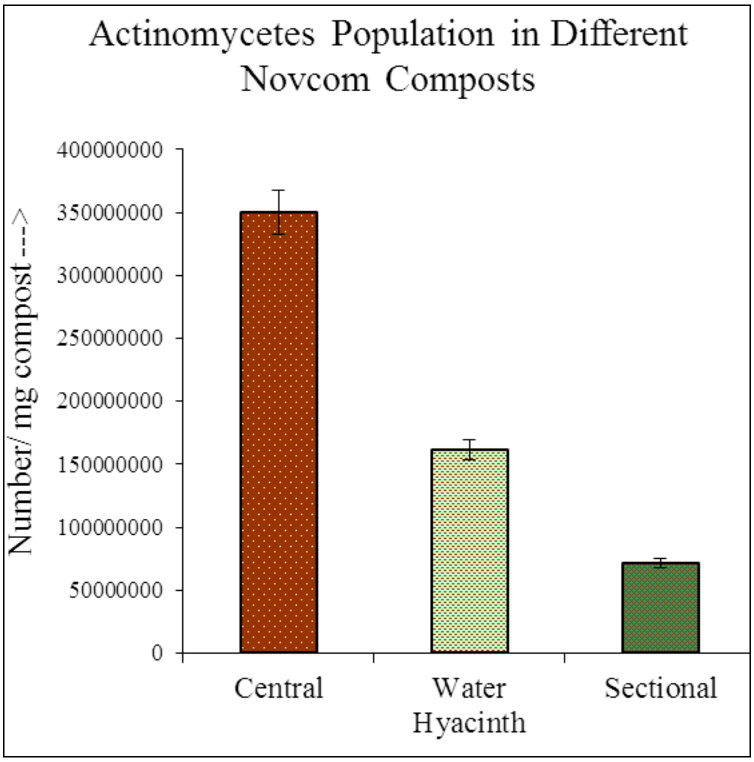


Fig. 15**:** *Comparative Study of Actinomycetes Population of Different Novcom Compost*.

Picture 5: *Mature Novcom Compost in W. Jalinga Tea Estate.*

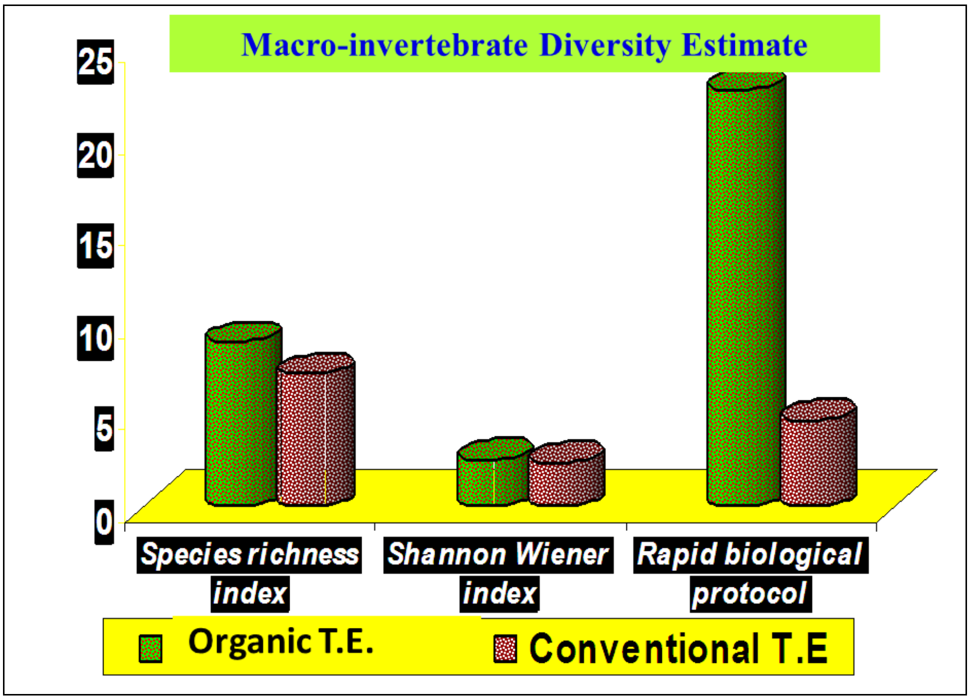


Fig. 16: *Comparative Study of Different Ecological Indices for Micro-Invertebrate Diversity Estimation of Stream Water in Organic and Conventional Tea Estates.*

Picture 6: *Stream Flowing through West Jalinga Tea Estate.*

Water Quality Analysis

Water quality analysis was done to determine the impact of different cultivation practices on the different quality parameters. The mean value of the different physicochemical variables of stream water from organic (Figure 16) and conventional tea estates are given in Table 1. The water pH varied from neutral to alkaline (7.11 to 7.88), while the conductivity ranged from 54.8 to 92.9. Free carbon dioxide in the water varied from 9.52 to 23.1 mg/litre. Both dissolved oxygen and total alkalinity were higher in the water obtained from the stream of organic tea estate (Picture 6) as compared to the conventional. The higher value of dissolved oxygen might be due to the increased photosynthetic activity of the green algae found on the submerged stones and pebbles. Nitrate concentration was found to be 6.8 to 8.2 times higher in the water samples collected from the conventional tea estate. Kramer et al [28] reported reduced N pollution from organic and integrated farming systems as compared to the conventional farming systems and found nitrate leaching to be few times more in the conventional farms as compared to its organic counterpart.

***Table 1:** Comparative Physicochemical Characteristics of Stream Water in Organic and Conventional Tea Gardens.*

Parameters	Organic under IRF Technology	Conventional Farming Practice	
	West Jalinga Tea Estate	Garden 1	Garden 2
Dissolved O_2 (mg/l)	5.48 ± 0.04*	4.5 ± 0.03	3.38 ± 0.03
Total alkalinity (mg/l)	36.56 ± 0.24	12.3 ± 0.29	19.5 ±0.23
Free CO_2 (mg/l)	9.52 ± 0.11	10.27 ± 0.13	23.1 ±0.17
pH	7.56 ± 05	7.11 ± 07	7.88 ±0.06
Conductivity (µScm^{-1})	92.95 ± 0.86	54.8 ± 0.89	67.12 ±0.97
TDS (mg/l)	42.9 ± 0.53	25 ± 0.32	38 ±0.39
NO_3 (mg/l)	0.19 ± 0.01	1.55 ± 0.02	1.3 ± 0.02

**Standard Error*

Deunert and Fohrer [29] found that organic farming resulted in substantial improvement in water quality by reducing the leaching of nutrients into ground and surface water. The results indicated that organic tea cultivation can have a positive influence on the quality of the associated water bodies. Especially nitrate pollution in water can be reduced to a great extent by switching over to organic, which also has favourable impact on the dissolved oxygen content.

Periphyton, Phytoplankton and Zooplankton Taxa in the Streams of the Tea Gradens

Diversity, distribution, abundance and variation in the biotic factors provide information of energy turnover in the aquatic systems [33]. In these systems phytoplankton is of great importance as a major source of organic carbon located at the base [34]. Their sensitivity and large variations in species composition are often a reflection of significant alteration in ambient condition within an ecosystem [35, 36]. The biological spectrum of the lentic fresh water bodies is multidimensional where phytoplankton, periphyton and zooplankton are useful in bio-monitoring the ecological disturbance caused by a number of physicochemical factors, sewage pollutants and other anthropogenic factors [37]. In the present study 27 different species under this group were found in the streams flowing through organic tea estates (Pictures 11, 12, 13, 14) in comparison to only 13 different species in case of the conventional tea estate (Table 3).

Macro-invertebrate and Vertebrate Taxa in Stream Water

Macro-invertebrates are an important component of stream ecosystems and are a link in the transfer of material and energy from producers to top level consumers and also act as excellent bio-indicators of stream health [30]. These are the organisms most commonly used for biological monitoring of freshwater ecosystems. This is because they are found in most habitats, have generally limited mobility, are quite easy to collect by way of well-established sampling techniques, and there is a diversity of forms that ensures a wide range of sensitivities to changes in both water quality and habitats [31, 32].

Under macro-invertebrate group, 10 different species were found under three different phylum/subphylum in the streams flowing through organic tea estates (Pictures 7–10). Whereas only 3 to 4 species were found under 3 different phylum/subphylum in the streams flowing through conventional tea estates (Table 2). At the same time 4 different species under vertebrates were found in the streams flowing through organic tea estate in comparison to only 1–2 different species in the streams flowing through conventional tea estates.

Table 2: *Comparative Distribution of Macro-Invertebrate and Vertebrate Taxa in Stream Water Flowing through Organic and Conventional Tea Gardens.*

Taxa	**Organic under IRF Technology**	**Conventional Farming Practice**		
	West Jalinga Tea Estate	**Garden 1**	**Garden 2**	
INVERTEBRATES				
Mollusca (Phylum)				
Gastropoda 1	+	-	-	
Gastropoda 2	+	+	-	
Gastropoda 3	+	+	+	
Gastropoda 4	+	-	+	
Gastropoda 5	+	-	+	**Picture 7: Gastropoda**
Lymnaeidae	+	-	-	
Insecta (Class under Arthropoda phylum)				
Mesovelia sp.	+	+	-	
Coleoptera	+	-	+	
Crustacea (Subphylum)				
Macrobrachium sp.	+	-	-	
Crab	+	-	+	**Picture 8: Macrobrachium sp.**
VERTEBRATES				
Pisces (Superclass under Gnathostomata subphylum)				
Fish 1	+	-	-	
Fish 2	+	+	+	
Fish 3	+	-	+	
Amphibia (Phylum)				
Limnonectes limnocharis	+	-	-	**Picture 9: Frog**

Picture 10: *Macro-invertebrate sampling site in W. Jalinga T.E.*

Table 3: *Distribution and Diversity of Periphyton, Phytoplankton and Zooplankton Taxa in the Streams of the tea Gardens.*

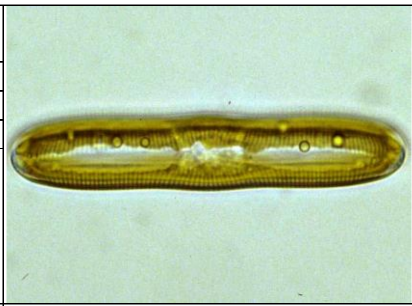
Taxa	**Organic under IRF Technology**	**Conventional Farming Practice**	
	West Jalinga Tea Estate	**Garden 1**	
Pinnularia	+	+	
Nitzschia	+	+	
Gyrosigma	+	+	
Eucocconeis	+	+	**Picture 11: *Pinnularia***
Bacillaria	+	-	
Rhoicosphenia	+	-	
Tabellaria	+	-	
Amphipora	+	+	
Neidium	+	-	
Diatomella	+	-	
Surirella	+	-	
Synoecocystis	+	-	**Picture 12: *Gyrosigma***
Anomoeonies	+	+	
Amphora	+	+	
Eunotia	+	-	
Zygnema	+	-	
Stauroneis	+	+	
Kentosphoera	+	+	
Oscillatoria	+	+	**Picture 13: *Zygnema***
Anabaena	+	+	
Algae 1	+	+	
Algae 2	+	-	
Algae 3	+	-	
Scenedesmus	+	-	
Brachionus	+	+	
Rotifera	+	-	
Microcystis	+	-	**Picture 14: *Scenedesmus***

Table 4: *Comparative Ecological Indices of Species Richness in Stream Water Flowing Through Organic and Conventional Tea Gardens.*

Ecological Parameters	**Organic under IRF Technology**	**Conventional Farming Practice**	
	West Jalinga Tea Estate	**Garden 1**	**Garden 2**
Abundance of Individuals/m^2	84.3 ± 0.74*	22 ± 0.43	34 ± 0.49
Abundance of Macro-invertebrates/m^2	55 ± 0.56	08 ± 0.01	16 ± 0.05
Total species Richness	10.3	08	06
Macro-invertebrates species Richness	6.66	04	01
Shannon-Wiener index	0.602	0.574	0.01
Ratio of Individuals in Numerically dominant Taxa	0.53 ± 0.2	0.33 ± 0.2	1.0 ± 0.3
Rapid Biological Protocol (RBP III)	14.62	4.19	4.8

**Standard Error*

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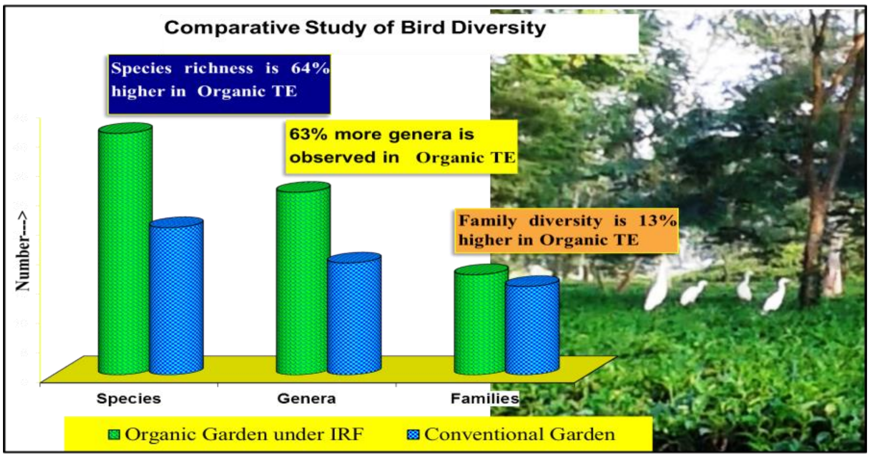

Fig. 17: *Comparative Study of Bird Diversity in Organic and Conventional Tea Estates.*

Table 5: *Comparative Study of Different Species of Bird in Organic and Conventional Tea Estate.*

Name of species	**Common Name**	**Organic T.E.**	**Conventional T.E.**		
			Garden I	**Garden II**	
Abroscopus hodgsoni	Broad billed flycatcher warbler	6	6	-	
Acridotheres fuscus	Jungle myna	7	2	1	
Acridotheres tristis	Common myna	11	5	-	*Bubulcus ibis*
Bubulcus ibis	Cattle egret	59	38	24	
Centropus sinensis	Crow pheasant or Coucal	7	7		
Copyschus saularis	Magbie robin	3	-	-	
Corvus macrophynchos	Jungle crow	21	-	-	
Dendrocita vagabunda	Indian treepie	4	1	-	
Dicaeum cruentatum	Scarlet backed flower pecker	7	3	3	Dicrurus annectans
Dicaeum erythrorynchos	Tickell's flower pecker	2	-	-	
Dicrurus annectans	Crow billed drongo	64	3	-	
Dicrurus remifer	Lesser racket tailed drongo	3	3	-	
Dicrusus adsimilis	Black drongo or King Crow	1	—	-	*Acridotheres fuscus*
Eudanamys scolopaca	Koel	9	8	6	
Halcyon smyrnensis	White breasted kingfisher	6	3	-	
Hypothymis azurea	Black napped flycatcher	7	5	-	
Megalaima zeylanica	Large green barbet	2	-	-	*Abroscopus hodgsoni*

					
Megaluris plaustris	Striated marsh warbler	5	3	-	
Milvus migrans govinda	Parian Kite	7	-	-	
Mirafra assamica	Bengal bush lark	2	-	-	*Milvus migrans govinda*

***Table 6**: Comparative Study of Different spices of Bird in Organic and Conventional Tea estates.*

Name of species	**Common Name**	**Organic T.E.**	**Conventional T.E.**		
			Garden I	**Garden II**	
Oriolus xanthus	Oriole (Black headed)	5	1	2	
Rallina fasciata	Red legged banded crake	1	-	-	
Picoides cathpharius	Crimson breasted woodpecker	1	-	-	*Psittacula krameri*
Psittacula krameri	Rose ringed parakeet	20	-	-	
Pycnonotus cafer	Red vented bulbul	12	17	-	
Pycnonotus cafer bengalensis	Red-vented Bulbul (bengalensis)	6	-	-	*Oriolus xanthus*
Pycnonotus jocusus	Red whiskered bulbul	5	6	5	
Streptopelia chinensis	Dove	12	-	-	
Gracupica contra	Pied myna	22	18	2	*Muscicapa ferruginea*
Upupa epops	Hoope	3	-	-	
Treron sphenura	Yellow green dove	5	-	-	
Streptopelia orientalis	Rufous turtle dove	3	-	-	
Alcedo atthis	Common kingfisher	2	-	-	*Gallirallus striatus*
Muscicapa ferruginea	Ferruginous flycatcher	1	-	-	
Gallirallus striatus	Salty breasted rail	1	-	-	
Turnix suscitator	Barred button quail	1	-	-	
Gecinulus grantia	Pale headed woodpecker	1	-	-	
Blythipicus pyrrhotis	Bay woodpecker	1	-	-	*Turnix suscitator*

Ecological Indices of Species Richness in Stream water

Comparative study of ecological indices of species richness in stream water flowing through Organic and Conventional tea gardens was also taken up in the present study. Different ecological indices *viz*., Abundance of Individuals/m^2, Abundance of Macro-invertebrates/m^2, Total species Richness, Macro-invertebrates species Richness, Shannon-Wiener index, Ratio of Individuals in Numerically dominant Taxa and Rapid Biological Protocol (RBP III) were evaluated to study the ecological diversity under two varying cultivation systems in the tea environment (Table 4).

All the indices showed comparatively higher value in the streams flowing through organic tea estate in comparison to its conventional counterparts. These studies clearly show a strong relationship between water quality and biodiversity measures in case of both the invertebrate and vertebrate species. The study revealed that, conventional practice in tea plantation reduce habitat quality in adjacent streams, reduce stream macro-invertebrate diversity, and shift the taxonomic composition of these communities toward families known to be less sensitive to environmental degradation.

Bird Diversity Study

A number of studies have focused on biodiversity in shaded agroforestry systems using birds as an indicator and highlighted their importance in conserving the habitat of various organism including birds [38, 39, 40]. Indiscriminate use of agro-chemicals has a negative impact on the bird diversity of the conventional tea estates.

At the same time, since most tea plantations strictly follow monoculture practices, biodiversity assemblages in such plantations are poor as compared to forest ecosystems [41, 42] and other agroforestry ecosystems, such as pine plantations [43], However, if the agro-ecosystems which are primarily meant for production of crops, are managed organically, traditionally or maintained with diverse shade trees the same can conserve significant amount of wild biodiversity with unique community assemblages of plants and animals [42, 44, 45, 46, 47, 48].

In this comparative biodiversity study, total 38 bird species were recorded in the organically managed W. Jaling Tea Estate, while the other two conventional tea estates recorded only 16 species (Tables 5 & 6). The short-term study highlighted that the organically managed tea plantations have great potential in harboring and conserving bird diversity as also found my other works in their study encompassing organic plantations [48]. The study showed that 64 % higher Species richness is in organic plantation in comparison to the conventional gardens. Similarly 63 % more genera and 13 % more family diversity was documented in the studied organic tea estate in comparison to conventional tea estates (Figure 17).

CONCLUSION

The study is a clinical proof regarding the impact of cultivation practice on the biodiversity within a tea agro-ecosystem. Switching over from the conventional chemical farming to a comprehensive organic practice caused enrichment of the ecological components within the tea agro-system, even while the status of the other co-factors remained same. Most importantly, notable changes were observed within a few years' time, which indicated that nature has an immense power to bounce back to its original state of equilibrium, if the desired environment is provided. Hence, it is worthwhile to trade the conventional farming system for a nature friendly organic package of practice that can preserve our ecology and biodiversity; in order to restore the sustainability in our crop production system before it gets too late.

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