MINERALIZATION OF SOIL NITROGEN, CARBON AND KINETICS OF ENZYMES UNDER COCONUT BASED CROPPING SYSTEM

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"MINERALIZATION OF SOIL NITROGEN, CARBON AND KINETICS OF ENZYMES UNDER COCONUT BASED CROPPING SYSTEM"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

%	-	Per cent
α	-	Alpha
β	-	Beta
μg	-	Microgram
Al	-	Aluminium
AEU	-	Agro Ecological Unit
B	-	Boron
BFI	-	Biological Fertility Index
C	-	Carbon
C D	-	Critical Difference
Ca	-	Calcium
CFU	-	Colony Forming Unit
cm	-	Centimeter
CRD	-	Completely Randomized Design
Cu	-	Copper
dS	-	Deci Siemen
EAN	-	Enzyme Activity Number
EC	-	Electrical Conductivity
et al.	-	And others
Fe	-	Iron

Fig.	-	Figure
g	-	Gram
hr	-	Hour
ha	-	Hectare
H_2O_2	-	Hydrogen peroxide
i.e.,	-	That is
K	-	Potassium
KAU	-	Kerala Agricultural University
kg	-	Kilogram
MBC	-	Microbial Biomass Carbon
MBN	-	Microbial Biomass Nitrogen
mg	-	Milligram
Mg	-	Magnesium
Mg m^{-3}	-	Megagram per meter cube
mM	-	Millimolar
mm	-	Millimeter
MN	-	Mineralizable Nitrogen
MNQ	-	Microbial Nitrogen Quotient
Mn	-	Manganese
MUB	-	Modified Universal Buffer
N	-	Nitrogen

Na	-	Sodium
O.C	-	Organic carbon
O.M	-	Organic matter
P	-	Phosphorus
PGPR	-	Plant Growth Promoting Rhizobacteria
pnp	-	Para nitro phenyl phosphate
POC	-	Particulate Organic Carbon
POP	-	Package of Practices
ppm	-	Parts per million
S	-	Sulphur
S. E	-	Standard Error
TN	-	Total Nitrogen
TPF	-	Triphenyl Formazon
TTC	-	Triphenyl tetrazolium chloride
viz.,	-	Namely
V_{max}	-	Maximum Velocity
WSC	-	Water Soluble Carbon
Zn	-	Zinc

Introduction

1. INTRODUCTION

Coconut (*Cocos nucifera* L.), widely known as 'Kalpavriksha' is an important perennial oil yielding crop of humid tropics. It is a traditional plantation crop of India and assumes the status of a high value commercial crop. Since India leads in both production and area coverage, and most of the acreage (90 %) in the country lies in the four southern states *viz.*, Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. Kerala ranks first in area (53.76 %) and production (45 %) followed by Tamil Nadu, Karnataka and Andhra Pradesh (CDB, 2015).

Coconut is one of the few crops in which intercropping is extensively practiced. In a coconut based cropping system, the vertical and horizontal spaces between the palms are utilized for intercropping. A coconut based cropping or farming system involves cultivation of compatible crops in the interspaces of coconut, and integration with other enterprises offers considerable scope for increasing production and productivity per unit area, time and inputs by more efficient utilization of the available resources. A variety of crops are tested as intercrops with varying degree of success. As per the research findings of Central Plantation Crops Research Institute, (CPCRI, 1990) various crops such as tubers, banana, vegetables, fodder grass, medicinal plants, spices etc can be grown in coconut so as to harness maximum sunlight and thereby the yield. Long term studies have indicated that repeated growing of same intercrop year after year is not advisable both from the point of view of coconut yield and intercrop yield.

The practice of coconut based cropping system provides food security through food sufficiency, nutritional foods rich in vitamins and minerals (nutrients), employment generation from farm diversification and ecological stability (Thomas *et al.*, 2010).

Banana is a very profitable intercrop and can be intercropped in one to three years or 25 years and above old coconut (Gopalasundaram and Nelliat, 1979). Banana is fast growing plant that bears fruit in less than one year (Gopalasundaram and Nelliat, 1979).

Vegetable intercropping under coconut palms is one of the popular intercropping practices in rural areas for many good reasons in Kerala. This intercropping practice requires short period of planting time, smaller area provides additional income to coconut farmers and nutritious food for farm communities (Hegde *et al.*, 1993). Vegetable intercropping such as tomato, eggplant, sweet pepper, squash, okra, ginger etc. is highly recommended in a coconut based cropping system.

The declining land availability made the farmers to cultivate fodder in coconut gardens to sustain a viable dairy unit. Tree fodder, guinea grass, legume fodder and congosignal fodder are found suitable in coconut garden.

Despite the intercrops and various components of coconut based cropping system, the nutrient dynamics, budgeting and balance sheet is of major concern now adays (Mini *et al.*, 2015).

Various soil quality indicators *viz.*, physical, chemical and biological have been used as tools to assess the fertility status of the soil and suggest management practices (Doran and Parkin, 1996). Soil microbial biomass is the main driving force in the decomposition of organic materials and is frequently used as an early indicator of changes in soil properties resulting from soil management and environment stresses in agricultural ecosystems. Soil microbial biomass carbon and nitrogen are the most labile pools in soils (Jenkinson and Ladd, 1981) and therefore the nutrient availability and productivity of agro ecosystems mainly depends on the size and activity of the microbial biomass. Microbial biomass determination provides estimates of the net flux of carbon and nitrogen through microbial pools and thus reflects the contribution of soil microorganisms as both a source and a sink of carbon and nitrogen in soil ecosystems.

Activities of major soil enzymes are also considered as sensitive parameters, which can be used as an early warning of changes in ecosystem before they are detectable (Andrews *et al.*, 2002). Any management induced change will be reflected readily on soil enzyme activities. The activities of major enzymes are used for the validation of changes in soil qualities for verifying the management induced changes in a sustainable cropping system. Mineralization of organic materials in soils is one of the key processes that enables plant growth and crop production because, as consequence of the mineralization process, available nutrients are released. Net mineralization is the result of two opposite processes gross mineralization (N release) and immobilization (N assimilation) by the microbial population.

In Kerala, there is dearth of information on soil biological regimes such as enzyme activities and microbial dynamics in various soils as most of research is focused on the soil physico-chemical characters. Hence there is a dire need to probe into these aspects in order to identify the fate of nutrients applied to the soil and also various reactions occurring in the soils under various cropping and farming situations. Only a few studies have been hitherto attempted to assess the dynamics and distribution of soil enzymes under various cropping systems especially coconut and rice based system. Hence the present study is envisaged to probe into the dynamics of major soil enzymes under various cropping systems (coconut) in two farming situations (organic and conventional) in mid laterite soils of AEU 9 with the following objectives:

- To assess the mineralization potential of soil nitrogen and carbon and to evaluate the kinetic parameters of agriculturally significant soil enzymes of coconut based cropping systems in midlaterite soils of Agro Ecological Unit (AEU) 9.

Review of Literature

2. REVIEW OF LITERATURE

Coconut (*Cocos nucifera* L.) is a resourceful crop providing food, health drink, medicine, shelter, fuel, fibre and timber. Coconut is highly agreeable for cultivating intercrops because of its wider spacing. Coconut based cropping systems are more favourable and stable for intensive and sustainable agricultural production. Diversification in coconut helps to conserve natural resources and protect environment. A variety of crops have been found suitable for growing under irrigated and rainfed conditions in coconut garden. Hence the present study was focused to assess the mineralization of soil nitrogen, carbon and enzyme kinetics in coconut based cropping system and this chapter reviews the important literature pertaining to the study.

2.1. COCONUT BASED CROPPING SYSTEMS

The success of a crop combination programme under coconut depends on the selection of compatible crop combinations in which, each crop will exploit a distinct and different zone of atmosphere and soil so that the individual competition for nutrients, moisture, space and solar radiation will be minimum. When the individual crops in the system utilise mutually exclusive rooting zones, the demand for additional moisture and nutrients need not be directly proportional to the adopted cropping intensity. Differential root activity under crop combination not only enables better utilisation of the native and added nutrients but also prevents loss of nutrients from mobility and leaching (Thampan, 1980).

An economic analysis of the coconut based cropping system at Kerala with aged coconut plant at the top layer, arecanut trailed by pepper and jackfruits, lime, mango, tamarind and breadfruit in the second layer, tapioca, banana and fruit plants in the third layer and vegetables and tuber crops in the lowest layer, gives an estimated annual net profit of Rupees Twenty thousand (Salam and Sreekumar, 1990).

Intercropping is growing two or more crops in the same piece of land simultaneously which is widely practiced by farmers, especially in the tropics. Particularly for farmers with small holdings, it is an advanced agro technique and is considered to be an effective and potential mean of increasing crop production per unit area and time (Ginigaddara *et al.*, 2016). The main concept of intercropping is to increase production and productivity. Moreover, intercropping gives a greater stability of yield over monocropping (Pathick and Malla, 1979). Besides, it ensures greater resource use efficiency (Reddy and Willey, 1981).

Magat (2004) reported that growing of intercrops in coconut garden produces more food and agricultural products, ensuring food security of the people in rural and urban areas and also generates jobs and livelihood, enhancing farm incomes thus alleviating poverty in farming communities.

Thomas *et al.* (2010) opined that the soil conservation measures and cropping systems had a significant impact on coconut yield. Adopting intercropping systems *viz.*, coconut + fodder grass, coconut + vegetable and coconut + pineapple resulted in increased yield of coconut compared to monocropping.

Gopalasundaram and Nelliat (1979) observed that banana is a highly profitable mixed crop in areas with good irrigation facilities. Experiments were conducted at CPCRI, Kasaragod to find out the suitable banana variety for coconut based cropping system and reported that the varieties like Peda pacha and Grosmichel were the highest yielders followed by Dwarf Cavendish in coconut based cropping systems.

Palaniswami *et al.* (2007) reported that under coconut based farming systems, Panniyur-1 pepper variety performed well and yielded 1.2 to 1.66 kg vine^{-1} year^{-1} and the highest yield was under 2/3rd recommended dose of fertilizer applied field (1.66 kg $vine^{-1}$).

Many tropical tubers like colocasia, cassava, elephant foot yam, sweet potato, chinese potato, greater yam and lesser yam are the most popular intercrops raised in coconut based cropping systems (Gopalasundaram and Nelliat, 1979; Hegde *et al.*, 1990). The tuber crops moderately meet the food requirements of a farm family and finds a place in the homestead gardens of Kerala (Varghese *et al.*, 1978).

The study conducted at Kasaragod reported that vegetables like brinjal, coccinia, snake gourd, bottle gourd and bitter gourd are the most compatible crops with coconut based cropping systems (Hegde *et al.*, 1993).

2.1.1. Physical properties

Maheswarappa *et al.* (1998) noticed that by adopting mixed farming system in coconut garden there was improvement in soil physical properties. There was a reduction in bulk density from 1.54 Mg m^{-3} to 1.40 Mg m^{-3}, increased water holding capacity from 24 % to 33.6 % and improvement in porosity from 38.20 % and 39.00 % and both in coconut basins and grass cultured plot.

Palaniswami *et al.* (2007) reported a higher water holding capacity, higher hydraulic conductivity and reduction in the bulk density under combined farming treatments with vegetables and banana compare to coconut monocropping.

Brar *et al.* (2015) conducted experiment on physical and chemical characteristics of the soil under different fertilizer treatments and observed that 100 % NPK and FYM treated plot was found to report lesser bulk density (1.49 g/ c m^3) in a coconut based cropping system. It was also observed that the ideal bulk density for sandy soil was less than 1.6 Mg m^{-3}, for silty soil less than 1.4 Mg m^{-3} and for clay soil less than 1.1 Mg m^{-3} (Arshad *et al.*, 1996).

Malik *et al.* (2014) conducted a study on the effect of different treatments on water holding capacity of the soils and observed that water holding capacity was more in the plot treated vermicompost + biofertilizer + chopped crop residue in a coconut based cropping system.

2.1.2. Electrochemical properties

2.1.2.1. pH

The nutrition, growth and yields of most of the crops decreases, when the pH is low and increases as the pH rises to an optimum level. Many crops grow best if the pH is close to neutral (Smith and Doran, 1996).

Sources of H^+ ions in soil solution include carbonic acid produced when carbon dioxide from root respiration, decomposition of organic matter and the soil atmosphere is dissolved in soil water (Tisdale *et al.*, 1985). Other sources of H^+ ions are reaction of aluminum ions with water, root release, reaction of sulphur compounds, nitrification of ammonium from fertilizers and organic matter mineralization, rain water and acid rain (Parfitt *et al.*, 1997).

Carboxylic, phenolic and hydroxyl groups of organic matter increases H^+ ion concentration in soil solution, there by soil acidity increases (Rao, 1993).

Study conducted by Mini *et al.* (2015) on nutrient use strategies for coconut based cropping system in Onattukara sandy tract of Kerala revealed that the pH of the soils ranged from extremely acid (<6.5) to neutral to slightly alkaline (<6.5). The problem of acidity has aggravated to extreme levels in soils due to heavy inputs of acid producing fertilizers, without regular application of lime to neutralize the acidity.

2.1.2.2. Electrical conductivity (EC)

Soil EC was used as an indirect indicator of the amount of nutrients available for plant uptake and salinity levels. Effective irrigation practices decreases the Electrical Conductivity. Addition of organic matter increases Electrical Conductivity by adding anions and cations and also the water holding capacity (WHC) (Smith and Doran, 1996). Addition of various salts through continuous and excess application of fertilizer in the agricultural land increases the EC of the soil (Nagaraj *et al*., 2002).

Ananthkumar (2011) observed a higher soil EC under mixed shade coffee compared to mono shade coffee due to the decrease in the leaching loss of salts under lesser impact of rain drops on the surface of soil.

2.1.3. Nutrient status

2.1.3.1. Major nutrients

Maheshwarappa *et al.* (1998) observed the highest organic carbon, nitrogen, phosphorus and potassium status under grass cultured plot. The secondary and micronutrient status showed the negative trend as that of nitrogen, phosphorus and potassium in soils. Guinea grass noticed higher available nitrogen, phosphorus and potassium compared to coconut + hybrid napier bajra intercropping among the grass cultures tried.

Nweke and Nnabude (2014) evaluated the effect of cultivation and fallow on the organic carbon, total nitrogen and available phosphorus concentration in aggregate fractions of four soils under coconut. The four soils used for the study are Ultisol, Entisol and two Inceptisols. The study revealed that the highest Organic carbon and total nitrogen content noticed in the soils of the order Entisol.

According to Lakshmi *et al.* (2007), a synergistic yield response to the application of phosphorus and potassium in the coconut and fodder based cropping system was noticed. Application of 150 kg P_2O_5 ha^{-1} and 200 kg K_2O ha^{-1} significantly increased fodder guinea grass yield from 85.8 to 88.4 t ha^{-1} respectively and a coconut yield of 98 to 107 nuts $palm^{-1}$ $year^{-1}$. It was also reported that the application of 200-150-200 kg N-P_2O_5-K_2O ha^{-1} plus 100 kg magnesium ha^{-1} and 1 kg boron ha^{-1} to guinea grass, along with a package of practice recommended dose of 88-57-112 kg N-P_2O_5-K_2O ha^{-1} to coconut recorded the highest yields of 94.5 t ha^{-1} of green fodder and 107 nuts $palm^{-1}$ $year^{-1}$.

The nitrogen, phosphorus and potassium content decreases with the soil depth due to lower leaching losses or fixation than higher uptake of N, P and K by crops (Sharma and Chowdhury, 2002).

Extensive soil acidification, excess levels of P and wide spread deficiencies of boron, calcium, magnesium and zinc are the major limitations to crop production in the Coconut based cropping system in Onattukara Sandy Tract, Kerala. Excess of available phosphorus in the soil impairs nutrient balance and affects micronutrient absorption by plants (Mini *et al.*, 2015).

Investigations were carried out by Maheswarappa *et al.* (2011) to study the impact of inorganic fertilizer substitutions by vermicompost on the coconut productivity under laterite soil at CPCRI, Vittal. Of the treatments *viz.*, recommended inorganic fertilizer (500 g N, 320 g P_2O_5 and 1200 g K_2O palm $year^{-1}$), 25 % of N in the form of vermicompost (9.6 kg $palm^{-1}$)+75 % of NPK, 50 % N in the form of vermicompost (19.2 kg $palm^{-1}$)+50 % of NPK, 75 % N in the form of vermicompost (28.8 kg $palm^{-1}$)+25 % NPK and 100 % N in the form of vermicompost alone (38.5 kg $palm^{-1}$) imposed, application of vermicompost in combination with inorganic fertilizer at 25 % vermicompost + 75 % was noticed higher yield than the other treatments.

2.1.3.2. Secondary and micronutrients

According to Lakshmi *et al.* (2007), application of magnesium and boron to guinea grass significantly increased the fodder and coconut yield. Application of 100 kg Mg ha^{-1} and 1 kg B ha^{-1} to guinea grass, along with a Kerala Package of Practice recommended dose of 88-57-112 kg $N\text{-}P_2O_5\text{-}K_2O$ ha^{-1} to coconut recorded the highest yields of 94.5 t ha^{-1} of green fodder and 107 nuts $palm^{-1}$ $year^{-1}$.

Mini *et al.* (2015) studied the nutrient use strategies for coconut based cropping system in Onattukara sandy tract, Kerala. It was also reported that Boron deficiency was noticed in 77 per cent of the soil samples and 85 per cent of samples are deficient in calcium and magnesium.

Magat and Secretaria (2007) recommended a fertilization for coconut and the cocao crop. There are two inorganic fertilizer recommendations for coconut using the combination of single fertilizers (ammonium sulfate and common salt for soils rich in potassium or potassium chloride (0-0-60) for soils deficient potassium) and using ready to apply multinutrient fertilizers as 14-5-20-0.02 (Boron).

2.1.4. Biological properties

A distinctive balance of physical, chemical and biological components contribute to maintaining the soil health (Ellert *et al.* 1997).

Soil fertility and crop production are affected by biological and chemical processes which are ultimately involved in the cycling of nutrient, affect fertilizer use efficiency, reflects microbial activity in soil and act as indicators of soil productivity. As soil is a part of global environment and supports all terrestrial forms, soil protection is therefore of high priority and through understanding of soil physical, chemical and biological activities is a vital factor in assuring that the soil remains healthy (Srinivasulu and Rangasamy, 2006).

A bioindicator is defined as an organism, part of an organism, the product of an organism, collection of organisms or biological process which can be used to obtain information on the quality of all or part of the environment (Killham, 2002). A number of bioindicators have been suggested for monitoring soil health and they include carbon and nutrient cycling, soil microbial biomass, soil animals, plants, and soil enzymes (Killham, 2002).

Bioindicators are important for resource managers in order to understand ecological changes within the soil ecosystem (Dale *et al.*, 2008). Dale *et al.* (2008) summarized the criteria for ecological indicators, they are sensitive to system stresses, easy to measure, anticipation of change in ecological system, being integrative, predicts changes, ability to respond to natural disturbances, variable with response and having the attention of measured parameters of spatial and temporal change anthropogenic stresses and changes over time.

2.1.4.1. Enzyme status of the soil

Enzymes in soils originate from soil, animals, plants and microorganisms and connected covalently, copolymerized, crosslinked, adsorbed and included in the microcapsules of soil particles (Girish and Ajit, 2011).

Soil enzymes have been reported as useful soil quality indicators due to their relationship to soil biology, being operationally practical, sensitive, integrative, ease to measure and described as "biological fingerprints" of past soil management, and relate to soil tillage and structure (Utoboand Tewari, 2014).

Soil enzymes are the mediators and catalysts of important soil functions like organic matter decomposition, nutrient release plant growth, transformation of native soil organic matter, N_2 fixation, nitrification, denitrification and detoxification of xenobiotics (Dick, 1997). Soil enzymes have a fundamental role in carbon, nitrogen, phosphorus and sulphur cycle (Karaca *et al.*, 2011).

The soil enzymatic activities are considered as a major index for soil organic carbon status and soil microbial activity (Bandick and Dick, 1999). Yuan and Yue (2012) opined that soil enzymatic activity is powerfully related with soil organic matter content. The higher organic matter provides enough substrate to support higher microbial biomass and higher enzyme production.

Enzyme activities are considerably affected by tillage (Kandeler *et al.*, 1999) and cropping system (Ekenler and Tabatabai, 2002). Romero *et al.,* 2010 observed that the organic fertilizers had positively higher effect on soil enzymes activity than the inorganic fertilizers.

2.1.4.1.1. Dehydrogenase

Dehydrogenase play a major role in the biological oxidation of soil organic matter by transferring hydrogen ions (H^+) from organic substrates to inorganic acceptors (Zhang *et al.*, 2010). Dehydrogenases are the most important and are used as an indicator of overall soil microbial activity (Gu *et al.,* 2009; Salazar *et al.*, 2011).

Dehydrogenase enzyme oxidizes soil organic matter and is considered to exist as an integral part of intact cells in the soil (Das and Varma, 2011).

Wolinska and Stepniewska (2012) reported that oxygen availability, soil moisture, pH, oxidation reduction potential, depth of the soil profile, organic matter content, temperature, season of the year and soil fertilization or pesticide use can directly affect activity of dehydrogenase in the soil environment.

Forest soil reported the highest dehydrogenase activity in autumn season while the disturbed soil from coal mines reported the lowest dehydrogenase activity along the soil erosion gradient (Kumar *et al.*, 2013).

Dehydrogenase activity decreases with increase in pH of soil (Batra and Manna, 1997) and the highest activity at a temperature close to optimum for the growth and development of microorganisms (Wolinska and Stepniewska, 2012).

Moeskops *et al.* (2010) conducted an experiment on the effect of organic and conventional farming practices on soil enzymatic activities. Soil fertility was maintained mainly with composted organic matter in organic farms and in conventional farms, combined fresh manure, chemical fertilizers and large amounts of pesticides. A strong negative impact of intensive fertilizer and pesticide use on dehydrogenase activity was noticed.

2.1.4.1.2. Phosphatases (Acid and Alkaline phosphatase)

Phosphatase activity is responsible for phosphorus metabolism in the soil (Li *et al.*, 2010; Rahmansyah *et al.*, 2009). When a soil shows phosphorus deficiency, acid phosphatase secretion from plant roots is increased to enhance the solubilization and remobilization of phosphate, thus influencing the ability of the plant to cope with P stressed conditions (Karthikeyan *et al.*, 2002; Mudge *et al.*, 2002; Versaw and Harrison, 2002).

Soil pH influences the rates of synthesis, release and stability of acid and alkaline phosphatases by soil microorganisms (Tabatabai 1994). Optimum pH for acid phosphatase was found to be 4 to 6 and for alkaline phosphatase the optimum pH was 8-10 (Speir and Ross, 1978).

Tabaldi *et al.*, 2007 observed that the acid phosphatases catalyze non specific hydrolysis of inorganic phosphate from phosphate monoesters at pH 4 to 6 and play a important role in the supply and metabolism of phosphate in plants. In plant roots, acid phosphatases are involved in the solubilization of macromolecular organic phosphates in soils, which can be utilized by plants (Panara *et al.*, 1990).

Krishna (2015) conducted experiment on the impact of organic farming practices on soil health, yield and quality of cowpea (*Vigna anguiculata subsp. Sesquipedalis* (L.) *verdcort*) and observed that the full recommended dose of vermicompost + PSM (phosphorus solubilising microorganism) treated soil showed the highest dehydrogenase and phosphatase activities.

2.1.4.1.3. β-glucosidase

β-glucosidase enzyme plays an major role in soils, it is involved in catalyzing the hydrolysis and biodegradation of β-glucosidase present in plant debris decomposing in the ecosystem (Ajwa and Tabatabai, 1994; Martinez and Tabatabai, 1997).

β-glucosidase is an enzyme involved in cellulose degradation of cellulose, plays an important role in the soil organic carbon cycle (Bilen *et al.*, 2010). Martinez and Tabatabai (1997) reported that β-glucosidase is very sensitive to pH changes and soil management practices and can be used as a good biochemical indicator for measuring ecological changes resulting from soil acidification.

β-glucosidase is the rate limiting enzyme in microbial degradation of cellulose to glucose and an important carbon energy source of life for microorganisms in the soil (Esen, 1993; Tabatabai, 1994). β-glucosidase activity was observed to be the highest in the soil samples taken from the systems enriched with organic matter (Piotrowska and Koper, 2010).

β-glucosidases are proteins, which are very sensitive to different natural and anthropogenic factors, their activity helpful in monitoring soil quality, especially soil subject to differentiated organic and mineral fertilization in various crop rotations (Bandick and Dick, 1999; Gianfreda and Ruggiero, 2006).

2.1.4.1.4. Protease

Protease enzymes originated from plants, animals and microorganisms, catalyze the hydrolysis of proteins to polypeptides and oligo peptides to amino acids involved in nitrogen cycle (Moreno *et al*., 2003) and play a significant role in mineralization of soil nitrogen (Ladd and Jackson, 1982).

Protease activity was an indicator of the biological capacity of soil for the enzymatic conversion of the substrate and also have an important role in the ecology of microorganisms in the soil ecosystem (Burns, 1982). Protease in the soil is generally associated with inorganic and organic colloids (Burns, 1982; Nannipieri *et al*., 1996).

Proteases such as exopeptidases catalyse the hydrolysis of the terminal amino acids of polypeptide chains, while endopeptidases catalyse the hydrolysis of the internal peptide bonds (Baker and Drenth, 1987).

Proteases derived from plant biomass and microbial processes are hypothesized to be significant due to their different kinetic properties and their responses to environmental factors across a range of ecosystems (Dick, 1997).

Proteolysis is an important process with regard to nitrogen cycling in many ecosystems and proteolysis is considered to be a rate limiting step during soil nitrogen mineralisation (Weintraub and Schimel, 2005).

2.1.4.1.5. Catalase

Catalase is an intracellular enzyme found in all aerobic bacteria and most facultative anaerobes but absent from obligate anaerobes (Alef and nannipieri, 1995).

Catalase decomposes peroxide and its activity depends upon microbial biomass, organic oxygen concentration, changes in CO_2 and activity of dehydrogenase, amidase, glucosidase and esterase in soils (Burns, 1982).

Catalase activity is measured by adding hydrogen peroxide and determining the rate of residual H_2O_2 remaining over time or the release of O_2 or by gas chromatography (Trevors, 1984).

Soil catalase activity higher under well-aerated condition (Brzezinska *et al.*, 2005).

2.1.4.1.6. Amylase

The α-amylases are synthesized by microorganisms, plants and animals whereas, β-amylase is synthesized mainly by plants (Bahadure *et al.,* 2010).

Amylase widely distributed in soils and plants and plays a important role in the breakdown of starch to glucose and oligosaccharides and β-amylase, which converts starch to maltose (Mitchell and Lonsane, 1990).

Higher heavy metal concentration in plants reduces the activity of amylase as repoted by Kondhare *et al.,* 2015.

Plants influence on the amylase enzyme activities of soil by directly supplying enzymes from their residues or excreted compounds, or indirectly providing substrates for the activities of microorganisms (Aiyer, 2000).

Soil amylase is responsible for the breakdown of complex polysaccharide like starch to ready available form of glucose (Sivaramakrishnan *et al.*, 2006).

2.1.4.2. Enzyme activity number

Soil enzymes are reported as useful soil quality biological indicators due to their relationship to soil biology, being operationally practical, integrative, sensitive, ease to measure and described as "biological fingerprints" of past soil management and relate to soil tillage and structure (Bandick and Dick, 1999) and are also indicative of fertility (Antonious, 2003), quality (Dick, 1997; Bucket and Dick, 1998), biological equilibrium (Frankenberger and Tabatabai, 1991).

Biological Fertility Index, for the different combinations of treatments were computed based on the activity of five different enzymes as proposed by Beck (1984) through enzyme activity number given by the equation EAN = 0.2{TPF+ catalase (%)/10 + phenol (μg)/40 + amino-N (μg)/40 + amylase (%)/20}.

The geometric mean of the assayed enzyme activities (GMea) was used as an soil quality index in order to compare 18 pairs of organic and neiboring conventional olive orchards in southern Spain (Garcia-Ruiz *et al.*, 2008). The geometric mean of the assayed enzyme activities was calculated as:

$$GMea = (AcPXAlPXGluXAryXDEhyXPN)^{1/6}$$

where, AcP, AlP, Glu, Ary, DEhy and PN are acid phosphatase, alkaline phosphatase, glucosidase, arylsulphatase and dehydrogenase activities and potential nitrification rate, respectively.

2.1.4.3. Enzyme kinetic parameters

Kinetic parameters (V_{max}, K_m) are considered to be constant for a specific enzyme under defined experimental condition, but may vary independently (Tabatabai and Bremner, 1971). Kinetic parameter implies the splitting velocity of enzyme substrate complex and therefore reflecting the conjugation affinity between the enzyme and substrate (Zhang *et al.*, 2010).

The enzyme kinetic parameters (V_{max} and K_m) of different enzymes (protease, amylase, urease, invertase, and dehydrogenase) were determined by Kujur and Patel (2014) in order to assess the metabolic response of soil. The V_{max} (maximum reaction velocity) represents a maximum rate of activity when all enzymes are saturated, due to the gradual accumulation of soil organic matter which markedly increased in forest soil as compared to fresh mine spoil. Smaller K_m value was noticed in forest soil as compared to fresh mine spoil, suggesting the greater affinity of soil enzymes for substrate in forest soil. The parameters V_{max} and K_m are useful markers to assess changes in microbial activity of soil, because they represent quantity and affinity of enzymes respectively (Nemergut *et al.*, 2008).

Soil enzyme kinetics (V_{max} and K_m parameter) may change due to nutrient, if nutrient addition causes more microbial growth, then it may increase enzyme activities (V_{max}). Long term N input results in a shift in microbial communities (Frey *et al.*, 2004; Wallenstein *et al.*, 2006; Allison and Martiny, 2008) which then may produce different types of isoenzymes with altered active sites and those that exhibit different enzyme substrate affinity (K_m).

The speed of reaction increased, as the concentration of enzyme and the concentration of substrate was increased. As there is more enzyme, it is able to react with more substrate at once, therefore increasing the rate of reaction. Thus, higher levels of enzyme or substrate mean there will be a higher turnover rate of product (Marx *et al.*, 2005). The reaction rate of enzymes was increased drastically as there are more enzymes and are able to react with more substrates.

2.1.4.4. Soil microbes

Soil microbes like bacteria, fungi and actinomycetes play a major role in ecosystem services. The huge metabolic diversity of soil microbes contribute to the cycling of all major elements and affects the structure and functions of soil ecosystems (Linden *et al.*, 1994).

Soil microorganisms play an important role in nutrient gaining of plants and are critical determinants of soil nutrient status, crop health and productivity (Glick, 1995). With the increasing emphasis on environmentally friendly practices, low input agriculture practice, there is an ever growing interest in the management of soil microbial communities to enhance plant growth and soil microbiological foundations of coconut based cropping system approach (George and Prabhu, 2003).

2.1.4.4.1. Bacteria

Bacteria are the smallest autonomously living, single celled organisms on earth. The size of the bacterial cells size ranged from 0.5 to 1.0 μm in diameter. Bacteria may occur as rods, cocci, or spirals and some bacteria common in soils (Woese *et al.*, 1990).

There are two types of bacteria that are beneficial to plants, one that can form a symbiotic relationship with the plant, which involves formation of specialized structures or nodules on host plant roots (Glick, 2005) and bacteria that are free living and interact with the roots in the soil (Zahir *et al.*, 2004; Glick, 2005).

The bacteria, have symbiotic root associations with the coconut palm. *Beijerinckia indica* possessing traits such as production of polysaccharides, biological nitrogen fixation and plant growth promoting properties has been found to have consistent rhizospheric association with coconut (Merilyn and Thomas, 1991).

Plant growth promoting rhizobacteria (PGPR) colonize the rhizosphere of many plant species and confer beneficial effects like increased plant growth and reduced susceptibility to diseases caused by phytopathogenic fungi, bacteria, viruses and nematodes (Kloepper *et al.*, 2004).

The number of bacterial species per gram of soil ranged from 2000 to 18000. Fungi contributes the largest part of the total microbial biomass in soils (Ritz *et al.*, 2004).

Bacteria are more effective in phosphorus solubilisation than fungi (Alam *et al.*, 2002). Among the whole microbial population, phosphorus solubilizing fungi are only 0.1 to 0.5 %, while phosphorus solubilizing bacteria constitute 1 to 50 % of phosphorus solubilisation potential in soil (Chen *et al.*, 2006).

The major soil organic matter decomposition agents are fungi, which constitute the majority of soil biomass. However, both bacteria and fungi involved in complex degradation of organic molecules that higher organisms cannot breakdown (Eilers *et al.*, 2010).

2.1.4.4.2. Fungi

Fungi are ubiquitous in both metal polluted and unpolluted soils and dominate the microbiota in acidic soils and it is known that certain fungal metabolites are capable of the immobilization of mobile metal species eg: cations and soluble metal ion complexes (Gladd, 1996).

Many free living and symbiotic fungi are capable of transforming insoluble metal compounds to soluble derivatives, a process of environmental and applied significance (Morley and Gladd, 1995).

Fungal species typically have a wide pH optimum, often covering 5–9 pH units without significant inhibition of their growth (Wheeler *et al.,* 1991; Nevarez *et al.,* 2009).

Arbuscular mycorrhizal fungi improves the uptake of immobile phosphate nutrients thereby improving growth of the plant (Smith and Read, 1997). Arbuscular mycorrhizal fungi are obligate biotrophs, which is a prerequisite to colonize host plants for new spore formation.

In coconut based multistoreyed cropping system, spores of vesicular arbuscular mycorrhizal fungi were reported in all the soil samples collected from the root zones of plants. Fungi numbers varied from plant to plant (8-420 spores 100 g^{-1} soil) and sample to sample of the same crop.

2.1.4.4.3. Actinomycetes

Actinomycetes are extensively distributed in different habitats and involved in vital processes. They are survive under extreme soil condition such as high salinity or low level of moisture, but actinomycetes are also promote plant growth (Hamdali *et al.*, 2008).

Favourable condition for actinomycetes under relatively dry and warm conditions and neutral soil pH (Dindal, 1990).

Actinomycetes are an widespread and diverse group of Gram positive, aerobic and mycelial bacteria and are one of the major communities of the microbial population present in the soil and they play an important role in soil cycles (Sanglier *et al.,* 1996). Several actinomycetes are economically most important because they are the producers of vitamins, antibiotics and enzymes (Lazzarini *et al.*, 2000).

Burck *et al.* (2003) reported that in agricultural land the actinomycetes population is higher compared to forest soils when analyzing pasture, forest and sugarcane plantations in different countries.

According to McCarthy and Williams (1992), salinity, organic matter, relative moisture, pH, temperature and vegetation are the important factors which control loads of actinomycetes in soil.

2.1.5. Mineralization of soil nitrogen and carbon

Mineralization is a continuous process, temperature is the most important factor affecting mineralization rates and the mineralization rate affects N release and distribution (Crohn, 2006).

Large amendment application to soil significantly increased the nitrogen supply to soils in a short term suggesting low N mineralization rates (Hartz *et al.*, 2000).

Hirzel *et al.* (2012) conducted study on effect of poultry litter and conventional fertilization on nitrogen mineralization and phosphorus, potassium, copper and zinc availability in an Andisol and noticed that nitrogen mineralization rate was higher (61.5 %) with the poultry litter treatment than with conventional fertilizer (23 %). Conventional fertilization was associated with high nitrogen availability prior to the start of incubation and slight immobilization during the first week, due to a more rapid conversion of urea into NH_4 which was then temporarily immobilized by the microbial biomass.

LeeAnna *et al.* (2013) conducted a study on estimation of net nitrogen mineralization for using an empirical modeling approach by scaling up site level measurements. The result showed that net nitrogen mineralization was higher in low elevation forests (82.9 kg ha^{-1} yr^{-1}), while grasslands (14.3 kg ha^{-1} yr^{-1}) had the lowest net nitrogen mineralization.

With increasing the N availability, net mineralization rates increases initially but then decreased over time (Alison and Aber, 2000).

A laboratory experiment was conducted by Agarwal *et al.* (2008) to study the effect of combinations of organic and inorganic sources of nutrients on mineralization of nitrogen and organic carbon with treatments *viz.,* control, wheat straw, starter nitrogen, FYM, FYM+N, wheat straw+N, rice straw and rice straw +N. Wheat straw, rice straw and FYM were applied at the rate of 5 t ha^{-1}, 5 t h^{-1} and 15 t ha^{-1} respectively with or without starter dose of nitrogen (for straw 20 kg N ha^{-1} and for FYM 90 kg N ha^{-1}) and were incubated for three months. The mineralization of nitrogen and carbon were measured quantitatively following incubation method and alkali trap method respectively. The amount of carbon mineralized from the soil was maximum with the rice straw and starter nitrogen treated soil showed the highest amount of nitrogen mineralized at each date of observation.

A study conducted by Borkotoki *et al.* (2010) to narrate the effect of bentonite clay and moisture regimes on nitrogen mineralization in Mollisols of Tarai region of Uttarakhand with eight treatments *viz.*, control (soil), nitrogen, FYM, wheat straw, FYM + nitrogen, wheat straw + nitrogen, rice straw and rice straw + nitrogen revealed that the highest cumulative mineralized nitrogen was found in case of nitrogen treated soil and the lowest mineralization was recorded in wheat straw.

2.1.5.1. Mineralizable nitrogen

Nitrogen is an essential nutrient in crop production and deficiencies can result in substantial yield losses (St.Luce *et al.,* 2011). Nitrogen is mineralized when microorganisms convert nitrogen in soil organic matter to ammonia, nitrate, and nitrite. The major source of soil N is mineral N (NH_4 and NO_3). Total N content in mineral soils is approximately 1 % of which 5 % is in the mineral form (Havlin *et al.*, 2005).

The optimum pH for mineralization is between 5 and 7 and it decreases with increasing pH and EC (Schnurer *et al.*, 1985). Greater cation exchange capacity (CEC) reduces leaching losses and increases soil N supply and soils with higher SOM content reported to have greater microbial activity and therefore higher mineralization rates (Sharifi *et al.*, 2008).

Potentially mineralizable N is an indicator of the soils capacity to supply N and it is hypothesized to release the fraction of soil organic nitrogen responsible for the release of mineral N from microbial action over a growing season (Sharifi *et al.*, 2007).

Experiments at Kasaragod by Hegde and Yusuf (1993) reported that nitrogen budget and balance studies in coconut + vegetable cropping system showed that the highest nitrogen removed was found in cowpea followed by chilli and snake gourd. At the end of third season, the nitrogen balance was observed to be the highest in the plot cultured with amaranthus, bottle gourd and brinjal (937.3 kg ha^{-1}) and the lowest for cowpea, bhendi and chilli cultivated plot (785.5 kg ha^{-1}) (CPCRI, 1990).

2.1.5.2. Microbial biomass carbon and Nitrogen

Soil microbial biomass represents the total mass of microorganisms that have values of <5000 Um^{-3} and constitutes 50 % dry weight ha^{-1} with diverse bacteria, fungi and micro faunal populations. These microorganisms act as biocatalyst in nutrient cycling and ecosystem functioning (Sridevi *et al.*, 2013).

Santos *et al.* (2012) observed that higher soil microbial biomass in organic farming soil and lower microbial biomass in conventional farming. Due to the high carbon inputs and soil carbon buildup, organic farming enhanced soil microbial biomass.

Microbial biomass carbon generally comprises 1 to 4 % of soil organic matter (Anderson and Domsch, 1989). The microbial biomass carbon content in the soil is considerably and positively correlated with total culturable microbial population, organic carbon %, nitrogen content and available water content (Velmourougane *et al.*, 2014).

Das and Dkhar (2012) studied the effect of microbial biomass carbon in rhizosphere soil with organic amendments and observed that there was an increased microbial biomass carbon (300-500 mg kg^{-1} soil) in organic amended soil.

Soil microbial biomass carbon was considerably higher in coconut root region soils when compared to that in other crops. Microbial biomass carbon was also influenced by the fertilizer levels at medium levels supported higher biomass carbon contents (Kavitha, 2012).

Kara and Bolat (2008) conducted study to determine the impact of different land uses on soil microbial biomass nitrogen and carbon using the chloroform fumigation extraction method. The average microbial biomass nitrogen were found as 100.90 µg g^{-1}, 129.99 µg g^{-1} and 42.60 µg g^{-1} respectively, for pasture, forest and agricultural soils. The average microbial biomass carbon was found as 898.47 µg g^{-1}, 1028.29 µg g^{-1} and 485.10 µg g^{-1} respectively, for pasture, forest and agricultural soils.

2.1.5.3. Soil organic carbon

Soil organic carbon has a great contribution to chemical, physical and biological properties of soil because it is a source of energy for the microbial biomass, plant available water, density and soil resilience, participates in nutrient storage and cycling, aggregate formation and stability, as well as influencing cation exchange capacity (Reeves, 1997).

Soil organic carbon plays an important role in enhancing crop production (Stevenson and Cole, 1999).

Soil organic carbon has the capacity to affect plant growth as both a source of energy and a trigger for nutrient availability through mineralization. Continuous application of manure and compost, and use of summer and or winter cover crops improves soil organic carbon (Edwards *et al.*, 1999).

In coconut rhizosphere, the highest content of organic matter (0.71 %) was reported in the no fertilizer treatment, which decreased to 0.51 % in the treatment of full dose of fertilizers. The organic matter content in the soil was high at lower fertilizer levels (Thomos *et al.,* 2010).

Sudha and George (2011) studied the effect of cropping systems, residue management and tillage practices on organic carbon sequestration in soils and reported an improvement in soil properties for better growth and production of intercrops in a coconut garden. Among the different cropping systems, coconut + pineapple cropping system noticed the highest organic carbon content of 1.30 % at the end of two years, whereas, the coconut + maize system noticed only 1.21 % soil organic carbon.

Sreeja (2015) conducted experiment on the evaluation of enriched composts for soil remineralisation and crop nutrition. In this study, soil 5 kg + mineral enriched vermicompost (rock dust 25 %) @ 20 t/ha + PGPR Mix-1(2 %) treated plot recorded a higher organic carbon (1.43 %) compared to other treatments.

2.1.5.4. Particulate organic carbon

Particulate organic carbon is biologically available and a source of carbon and energy for soil microorganisms (Gregorich and Janzen, 1996). POC is an active fraction of SOC responds to soil management practice (Bayer *et al.*, 2001).

Under minimum soil disturbance, carbon present in particulate organic matter can accumulate rapidly and may even provide an early indicator of changes in soil organic carbon under different management practices (Cambardella and Elliott, 1992).

Carter (2002) reported that POC as an early indicator, which is more sensitive to changes in soil organic carbon due to agricultural management.

2.1.5.5. Hot water soluble carbon

Hot water soluble organic carbon (HWSOC) is a direct organic substrate for soil microorganisms (McGill *et al.*, 1981). Water soluble organic carbon is a most labile and mobile form of C. Concentration of water soluble and bio-available SOC have been reported to be high in agricultural soils (Boyer and Groffiman, 1996).

Agricultural soils might support greater rate of microbial activity than forest soils due to increased production of water soluble carbon (Saviozzi *et al.*, 1994).

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled "Mineralization of soil nitrogen, carbon and kinetics of enzymes under coconut based cropping system" was carried out in coconut based cropping systems *viz.,* Coconut + Fodder grass, Coconut + Banana, Coconut + Pepper, Coconut + Tuber and Coconut + Vegetable under organic and conventional farming situations of the mid laterite soils of Kerala (AEU 9) in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani during March 2015 to June 2017. The study was envisaged to characterize the coconut based cropping systems on the basis of chemical and biological parameters under two farming situations *viz.,* organic and conventional and to assess the biological fertility status of the soil. The details of the materials and methods followed are outlined in this chapter in the fore coming paragraphs.

3.1. LOCATION DETAILS

The study area, covered the mid laterite soils of Kollam districts *viz.,* Sadanandapuram, Anchal and Ayoor.

3.2. SOILS (AEU 9)

The south central laterites agro-ecological unit is delineated to represent midland laterite terrain with typical laterite soils and short day period. The climate is tropical humid monsoon type (mean annual temperature 27.6 ^{0}C; rainfall 2519 mm) with a dry period of around three and half months. Unlike the southern counterpart, the strongly acid, lateritic clay soils herein are gravelly and often underlain by plinthite. The lowlands have strongly acid, low active, non gravelly clay soils with impeded drainage conditions.

The study area extends between $8^{0}55'44"$ to $9^{0}21'09"$ N latitude and $76^{0}23'13"$ to $76^{0}41'16"$ E longitude.

3.3. LAND USE

Mono-cropped rubber and coconut intercropped with a variety of annual and other perennial crops was the major land use in uplands and rice, tapioca, banana and vegetables were prominent in the lowlands. The Agro Ecological Unit (AEU) 9 covers around 47,023 ha (18.90 %) in the district.

3.4. EXPERIMENTAL DETAILS

Design	:	Factorial Completely Randomized Design (CRD)
No. of treatments	:	10
No. of samples per cropping system	:	5
Total number of samples	:	50
Sampling time	:	August 2016
Location	:	Mid laterite soils of Kollam District-AEU9

Table 1. Treatment details

Treatments	Details
Coconut based cropping systems	
C_1	Coconut + Fodder grass (Hybrid Napier grass)
C_2	Coconut + Banana
C_3	Coconut + Pepper
C_4	Coconut + Tuber (Tapioca)
C_5	Coconut + Vegetable (Bitter gourd)
Farming situations	
F_1	Organic
F_2	Conventional system (Integrated)

Plate 1. A general view of Coconut + Pepper cropping system

Plate 2. A general view of Coconut + Tuber cropping system

The management practices adopted for each farming situation (organic and conventional) under each cropping system were found to be specific for each crop and similar among the replicated sampling sites.

3.5. EXPERIMENTAL METHODS

3.5.1. Collection and Preparation of Soil Samples

The soil samples from both organic and conventional fields of coconut based cropping systems were collected by random sampling technique. Five samples each were collected from both organic and conventional fields. The samples were collected and stored in polythene bags and a part of the sample was stored in deep freezers to ensure the viability of microorganisms. The rest of the samples were dried in shade, powdered with wooden mallet, sieved using 2 mm sieve for carrying out the analysis for physical, chemical and stored in polythene bags for biological parameters.

3.5.2. Characterization of Soils

3.5.2.1. Physical and Chemical Characterization

Various physical and chemical parameters were analysed by using the standard procedures as furnished in Table 2.

Table 2. Standard analytical methods

Sl. No.	Soil Properties	Method	Reference
	Physical Properties		
1	Bulk density	Core method	Gupta and Dakshinamurthy (1980)

2	WHC	Core method	Gupta and Dakshinamurthy (1980)
3	Porosity	Core method	Gupta and Dakshinamurthy (1980)
	Chemical Properties		
4	pH	pH meter (soil and water taken in a ratio of 1:2.5 w/v)	Jackson (1973)
5	EC	Conductivity meter (soil and water taken in a ratio of 1:2.5 w/v)	Jackson (1973)
6	Available N	Alkaline potassium permanganate method	Subbiah and Asija (1956)
7	Available P	Bray No.1 extraction and estimation using spectrophotometer	Bray and Kurtz (1945)
8	Available K	Neutral Normal NH_4OAc extraction and estimation using flamephotometer	Jackson (1973)
9	Available Ca and Mg	Versanate titration method	Jackson (1973)
10	0.5 N HCl extractable Fe, Mn, Zn and Cu	Atomic Absorption Spectrophotometer	Sims and Jhonson (1991)
11	Hot water extractable B	Spectrophotometer	Jackson (1973)

3.5.2.2. Biological Activity – Enzyme assay

3.5.2.2.1. Dehydrogenase Activity (μg of TPF released g^{-1} soil 24 h^{-1})

The dehydrogenase activity was measured by the procedure described by Casida *et al*. (1964).

Plate 3. A view of soil dehydrogenase enzyme activity study

Plate 4. A view of soil acid phosphatase enzyme activity study

One gram of air dried sample blended with 0.2 g $CaCO_3$, 1 ml of 3 per cent 2, 3, 5 - triphenyl tetrazolium chloride (TTC) and distilled water (2.5 ml) was added, mixed well and kept for incubation (24 hours) at room temperature (37 ^{0}C). After 24 hours, methanol (10 ml) was added and shaken for one minute. The sample was then filtered using a glass funnel plugged with non absorbent cotton and the whole amount of soil in the tube was transferred into the glass funnel by washing with methanol. The tube was washed repeatedly and the soil was transferred into the funnel. The reddish colour in the non absorbant cotton vanished while washing with methanol. Filtrate which was red in colour was made up to 100 ml with methanol and the colour intensity was measured using spectrophotometer at 485 nm. The concentration of dehydrogenase in the sample was obtained by plotting standard curve drawn by using tri phenyl formazon (TPF) as standard.

3.5.2.2.2. Acid Phosphatase Activity (µg of p-nitrophenol released g^{-1} of soil 24 h^{-1})

The acid phosphatase activity of soils was determined using the procedure described by Tabatabai and Bremner (1969). The enzyme activity was expressed in µg of p-nitrophenol released g^{-1} soil h^{-1}on dry weight basis at 37 ^{0}C at pH 6.5.

In a 100 ml volumetric flask, 1gm soil was weighed. Toluene (0.2 ml) and modified universal buffer having pH 6.5 (4 ml) were added into the flask, followed by 1 ml of 0.05 M p-nitrophenyl phosphate and kept in the incubator after swirling the flask for one hour at 37 ^{0} C. After incubation period, 1 ml $CaCl_2$ (0.5 M) and 4 ml NaOH (0.5 M) was added. The filtrate with yellowish colour was collected and read in spectrophotometer at 420 nm. The concentration of p-nitrophenyl phosphate in the filtrate was determined by plotting standard curve.

3.5.2.2.3. β-glucosidase Activity (µg pnp D- glucosidase g^{-1} soil h^{-1} X 10^{-4})

Eivazi and Tabatabai (1988) described procedure for estimating the activity of β-glucosidase in soil samples.

One gram of soil was taken and modified universal buffer of pH 6 (10 ml) and 1 ml p-nitrophenyl β-glucopyranoside (0.5 M) was added into it, mixed thoroughly and incubated for one hour at 37 ^{0}C. After incubation, 1 ml of 0.5 M $CaCl_2$ was added and then 4 ml Tris buffer (pH 10) was also added. The yellow colour of the filtrate was read at 405 nm in spectrophotometer.

3.5.2.2.4. Protease activity (µM of amino nitrogen hydrolysed g^{-1} soil h^{-1})

Ladd and Buttler (1972) describedthe procedure for estimating activity of protease in soil samples.

One gram soil was taken in vial, 2 ml tris – HCl buffer (0.05 M, 8.5 pH) and 2 ml of 1 % casein was added. It was then incubated for 2 hours. 1 ml of 13.5 % TCA was added to the same vial and centrifuged at 2000 rpm for 20 min. 1 ml supernatant was taken in volumetric flask, 1ml of 3.7 % Na_2CO_3 and 1 ml of 0.06 % $CuSO_4$ were added and incubated for 30 minutes. After incubation 1ml of folin cialcatechu reagent was added. After 15 minutes, the filtrate with green colour was read in spectrophotometer at 570 nm.

3.5.2.2.5. Catalase activity (% of H_2O_2 hydrolysed g^{-1} soil h^{-1})

Kuprevich (1951), Johnson and Temple (1964) described the procedure for estimating activity of catalase in soil samples.

Two gram of soil was taken and added 40 ml distilled water and 5 ml of 30 % H_2O_2 shaken for 20 min and added 5 ml of 3 N H_2SO_4. It was then filtered through whatman filter paper and 25 ml aliquot was taken and titrated with 0.05 M $KMnO_4$.

3.5.2.2.6. Amylase activity (µM of maltose g^{-1} soil)

Hofmann (1963), Kelley and Rodrigue–Kabana (1975) described the procedure for estimating activity of amylase in soil samples.

Plate 5. A view of the soil protease enzyme activity study

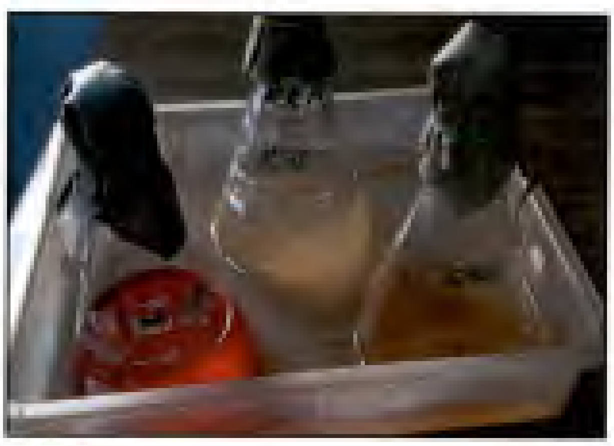

Plate 6. A view of the media (Nutrient agar, rose Bengal agar and kenit) of the soil microbial population study

Five gram of soil was taken in 50 ml conical flask and 1.5 ml of toluene was added, shaken for 15 min and 10 ml distilled water and 5 ml 2 % solution of soluble starch were added. The flask was stoppered and placed it in incubator for five hours at 37 ^{0}C and 15 ml distilled water was added and mixed well. 10 ml suspension was centrifused to produce clear supernatant, 1 ml of supernatant was then analysed for reducing sugar by a modified Nelson-Somogyi method.

3.5.2.2.7. Microbial load (log cfu g^{-1} soil)

Microbial counts in the soil samples were enumerated by serial dilution technique given by Timonin (1940).

Table 3. Media used for estimation of microbial population

Sl. No.	Microflora	Media used	Reference
1	Bacteria	Nutrient Agar medium	Atlas and Parks (1993)
2	Fungi	Martin's Rose Bengal Agar	Martin (1950)
3	Actinomycetes	Ken knight's agar medium	Cappuccino and Sheman (1996)

3.5.2.2.8. Computation of Biological Fertility Index Using Enzyme Activity Number (EAN)

Biological Fertility Index (BFI), for the different combinations of treatments was computed based on the activity of five different enzymes *viz.*, dehydrogenase, catalase, acid phosphatase, protease and amylase proposed by Beck (1984) through

Enzyme Activity Number (EAN). The Enzyme Activity Number for the different treatments was computed using the formula.

EAN = 0.2{TPF+ catalase (%)/10 + phenol (µg)/40 + amino-N (µg)/40 + amylase (%)/20}.

3.5.3. Lab incubation studies

3.5.3.1. Enzyme Kinetics [Michaelis – Menten Constant (V_{max} and K_m)]

The kinetics parameters K_m and V_{max} of the three major soil enzymes, urease, acid phosphatase and dehydrogenase were worked out based on the Line-Weaver-Burk plot in the Coconut + Banana cropping system under organic farming situation with high Biological Fertility Index (BFI). Varying concentrations of substrates were added to the soil and the activity of the enzymes were estimated.

When 1/V is plotted against 1/S, a straight line graph is obtained in Line-Weaver-Burk method, where V is the velocity and S is the substrate concentration. The slope is K_m/V_{max}, the intercept on the ordinate is $1/V_{max}$ (Vaughan and Ord, 1991).

Six concentrations each of urea solution (0.005, 0.010, 0.015, 0.020, 0.035 and 0.040 mol l^{-1}), p-nitrophenyl phosphate solution (0.0005, 0.001. 0.0025, 0.005, 0.015 and 0.050 mol l^{-1}) and tri phenyl tetrazolium chloride solution (0.003, 0.007, 0.010, 0.020, 0.030 and 0.050 mol l^{-1}) were the substrates for different enzymes urease, acid phosphatase, dehydrogenase respectively and the incubation study was carried out.

3.5.3.2. Mineralization studies of soil nitrogen

3.5.3.2.1. Total nitrogen (%)

Total nitrogen was estimated by the micro-Kjeldahl method as per procedure suggested by AOAC (1995) which included three steps: Digestion, distillation and titration.

Digestion: 1g soil sample with 10 ml H_2SO_4 and 5 g catalyst mixture.

Distillation: 20 ml 2 % boric acid with mixed indicator and 40 ml 40% NaOH.

Titration: Against 0.02 N H_2SO_4.

3.5.3.2.2. Microbial biomass nitrogen (mg of N g^{-1} soil)

Biomass nitrogen was determined by the fumigation–incubation technique outlined by Brookes *et al*. (1985).

20ml of extract was digested using Kjeldahl digestion, and the digest was analyzed in the autoanalyzer for total nitrogen. The difference between N in the fumigated and non-fumigated samples was the chloroform labile nitrogen pools and it was proportional to microbial biomass nitrogen.

3.5.3.2.3. Mineralizable nitrogen (mg kg^{-1})

Potential mineralizable soil nitrogen was determined by the method outlined by Standford and Smith (1972).

Mineral nitrogen forms was removed and the leachate was analysed for mineralized nitrogen by using the equation $N_{mac} = N_0 (1- e^{kt})$

N_{mac} = Mineralized nitrogen accumulated at time t

N_0 = Potentially mineralizable nitrogen

K = Mineralization constant

3.5.3.2.4. Microbial nitrogen quotient

Microbial nitrogen quotient was computed as the ratio between microbial biomass nitrogen to total nitrogen.

3.5.3.2.5. Percentage of mineralizable N to total nitrogen

Percentage of mineralizable nitrogen to total nitrogen was calculated as the ratio between mineralizable nitrogen to total nitrogen and multiplied with 100.

3.5.3.3. Mineralization studies of soil carbon

3.5.3.3.1. Soil organic carbon

Soil organic carbon was determined by Walkley and Black's (1934) rapid titration method.

3.5.3.3.2. Hot water soluble carbon

Hot water soluble carbon was determined by the method described by McGill *et al.* (1986).

Ten g soil sample was taken in a centrifuge tube and 20 ml distilled water was added, heated, shaken it for 1 hour, centrifuged for 20 minutes at 9000-10000 rpm and the aliquot was filtered in a beaker. Ten ml of aliquot was taken in 250 ml conical flask and 2 ml 0.2 N $K_2Cr_2O_7$ was added and then 10 ml of conc. H_2SO_4 and 5ml ortho phosphoric acid were added and the conical flask was kept on water bath at 100 ^0C for 30 minutes and titrated the contents in flask with 0.01 N FAS. A blank was also done simultaneously.

Plate 7. A view of the soil microbial biomass carbon study

3.5.3.3.3. Particulate organic carbon

Particulate organic carbon (POC) was determined by the method described by Camberdella and Elliott (1992) and Hassink (1995).

Fifty gram soil sample was dispersed in 150 ml of 0.5 per cent sodium hexametaphosphate solution by shaking for 15 hours on a reciprocating shaker. The dispersed soil sample was passed through > 53 μm sieve. After rinsing several times with water, the material that was retained on the sieves were collected and dried at 50°C overnight. Sample was ground and analysed for total carbon by Walkley and Black's (1934) rapid titration method.

3.5.3.3.4. Microbial Biomass Carbon (mg of CO_2 g^{-1} soil)

Biomass carbon was determined by the fumigation–incubation technique outlined by Jenkinson and Ladd (1981).

Total organic carbon was determined on a TOC analyser. The difference between carbon in the fumigated and non fumigated samples was the chloroform labile carbon pool which was proportional to microbial biomass carbon.

3.6. STATISTICAL ANALYSIS

The data generated from the experiments were subjected to the analysis of variance as per the design, Factorial CRD and their significance was tested using F test (Snedecor and Cochran, 1975). Critical difference (CD) was calculated at 0.05% probability levels using statistical tools.

Results

4. RESULTS

The study entitled "Mineralization of soil nitrogen, carbon and kinetics of enzymes under coconut based cropping system" was carried out in coconut based cropping systems *viz.,* Coconut + Fodder grass, Coconut + Banana, Coconut + Pepper, Coconut + Tuber and Coconut + Vegetable of both organic and conventional farming systems. The soil samples were analyzed in the laboratory for various physical, chemical and biological parameters for the computation of Biological Fertility Index (BFI), assessing the kinetic parameters of enzymes and the mineralization of carbon and nitrogen. Results of the data that was expressed based on statistical analysis during the course of investigation and are presented in this chapter.

4.1 PHYSICAL PROPERTIES OF SOILS UNDER COCONUT BASED CROPPING SYSTEM

4.1.1. Bulk density

The data on the bulk density of the coconut based cropping system was statistically analysed (Table 4) and it was noticed that it was significantly influenced by cropping systems, farming systems and their interactions. The mean values for bulk density ranged from 1.36 Mg m^{-3} to 1.59 Mg m^{-3}. The highest mean value was recorded by the Coconut + Fodder (1.59 Mg m^{-3}) cropping system, while the lowest mean value was noticed in Coconut + Vegetable (1.36 Mg m^{-3}) cropping system. In the case of interactions, the mean values for bulk density ranged from 1.30 Mg m^{-3} to 1.63 Mg m^{-3}. The highest bulk density value was recorded in conventional farming system of Coconut + Vegetable with a mean value of 1.63 Mg m^{-3} which was on par with conventional farming system of Coconut + Banana (1.60 Mg m^{-3}) and the lowest bulk density was observed in organic farming system of Coconut + Vegetable with a

Table 4. Physical properties of the soils under coconut based cropping system-(AEU 9)

Treatments	Bulk density ($Mg\ m^{-3}$)	Water holding capacity (%)	Porosity (%)
C_1	1.59	14.54	29.30
C_2	1.52	14.27	34.10
C_3	1.38	14.94	41.60
C_4	1.42	18.53	40.60
C_5	1.36	15.93	41.50
F_1	1.40	18.10	38.52
F_2	1.50	15.10	36.32
C_1F_1	1.55	16.73	28.00
C_2F_1	1.44	17.20	36.00
C_3F_1	1.33	13.69	44.60
C_4F_1	1.41	19.86	41.80
C_5F_1	1.30	16.02	42.20
C_1F_2	1.63	12.34	30.60
C_2F_2	1.60	11.33	32.20
C_3F_2	1.43	16.19	38.60
C_4F_2	1.43	17.20	39.40
C_5F_2	1.43	15.83	40.80
CD- C (0.05)	0.02	0.87	2.23
CD- F (0.05)	0.01	0.55	1.41
CD- C F (0.05)	0.02	1.23	NS

NS: Non significant

C_1 - Coconut + Fodder grass
C_2 - Coconut + Banana
C_3 - Coconut + Pepper
C_4 - Coconut + Tuber
C_5 - Coconut + Vegetable

F_1 - Organic farming
F_2 - Conventional farming

mean value of 1.30 Mg m^{-3} which was on par with organic farming system of Coconut + Pepper (1.33 Mg m^{-3}).

4.1.2 Water holding capacity

Statistical analysis of the data indicated that the water holding capacity of the coconut based cropping system was significantly influenced by the cropping systems, farming systems and their interaction effects (Table 4). The mean values for water holding capacity ranged from 14.27 % to 18.53 %. The highest mean value was recorded by Coconut + Tuber (18.53 %) cropping system and the lowest mean value was noticed in Coconut + Banana (14.27 %) cropping system which was on par with Coconut + Fodder (14.54 %) cropping system. With respect to interaction effects, the mean values for water holding capacity ranged from 11.33 % to 18.53 %. The highest mean value was observed in organic farming system of Coconut + Tuber (19.86 %) which was on par with Coconut + Tuber under conventional farming system while the lowest mean value was observed in conventional farming system of Coconut + Banana (11.33 %).

4.1.3 Porosity

Statistical analysis of the data on porosity revealed that the porosity was significantly influenced by the cropping systems and farming systems and it was non significant with respect to interaction effects (Table 4). The mean values for porosity ranged from 29.30 % to 41.60 %. The highest mean value was recorded in Coconut + Pepper (41.60 %) cropping system, which was on par with Coconut + Tuber (40.60 %) and Coconut + Vegetable (41.50 %) cropping system while the lowest mean value was observed in Coconut + Fodder (29.30 %) cropping system. With respect to the interaction effects, the mean values for porosity ranged from 28.00 % to 44.60 %. The highest porosity was noticed in organic farming system of Coconut + Pepper with a mean value of 44.60 % while the lowest mean value was recorded in organic farming system of Coconut + Fodder (28.00 %).

4.2 ELECRO-CHEMICAL PROPERTIES OF SOILS UNDER COCONUT BASED CROPPING SYSTEM

4.2.1 Soil reaction (pH)

Cropping systems, Farming systems and their interactions with farming systems were found to have significant effect on pH of the soils (Table 5). The mean values for pH ranged from 4.54 to 5.18. The highest mean value was noticed in Coconut + Vegetable (5.18) cropping system, which was on par with Coconut + Banana (4.99) and Coconut + Tuber (4.98) cropping system. The lowest pH was observed in Coconut + Fodder cropping system with a mean value of 4.54. With respect to interaction effects, the mean values for pH was ranged from 4.01 to 5.33. The highest mean value was noticed in organic farming of Coconut + Vegetable (5.33) which was on par with conventional farming system of Coconut + Banana (5.17) while the lowest pH was recorded in conventional farming system of Coconut + Fodder with a mean value of 4.01.

4.2.2 EC

In the case of EC the interaction effect of cropping systems and farming systems alone was found to have significant effect (Table 5). The mean values for EC (interaction effects) ranged from 0.26 dSm^{-1} to 0.45 dSm^{-1}. The highest mean value for the interaction effect was recorded in conventional farming system of Coconut + Fodder (0.45 dSm^{-1}) cropping system and the lowest EC was recorded in conventional farming system of Coconut + Banana (0.26 dSm^{-1}) and conventional farming system of Coconut + Pepper (0.26 dSm^{-1}). Even though the effect of cropping systems was found to be non significant on EC, the highest and lowest mean value were recorded from Coconut + Fodder (0.39 dSm^{-1}) and Coconut + Banana (0.31 dSm^{-1}) cropping system respectively.

Table 5. Electro-chemical properties of the soils under coconut based cropping systems-(AEU 9)

Treatments	pH	EC ($dS\ m^{-1}$)
C_1	4.54	0.39
C_2	4.99	0.31
C_3	4.78	0.33
C_4	4.98	0.32
C_5	5.18	0.35
F_1	4.96	0.35
F_2	4.82	0.32
C_1F_1	5.06	0.34
C_2F_1	4.82	0.36
C_3F_1	4.52	0.39
C_4F_1	5.09	0.33
C_5F_1	5.33	0.35
C_1F_2	4.01	0.45
C_2F_2	5.17	0.26
C_3F_2	5.04	0.26
C_4F_2	4.87	0.30
C_5F_2	5.02	0.34
CD- C (0.05)	0.03	NS
CD- F (0.05)	0.02	NS
CD- C F (0.05)	0.04	0.06

NS: Non significant

C_1 - Coconut + Fodder grass
C_2 - Coconut + Banana
C_3 - Coconut + Pepper
C_4 - Coconut + Tuber
C_5 - Coconut + Vegetable

F_1 - Organic farming
F_2 - Conventional farming

4.3 CHEMICAL PROPERTIES OF SOILS UNDER COCONUT BASED CROPPING SYSTEM

4.3.1 Major nutrient status

The results pertaining to the major nutrient status of the soils under coconut based cropping systems are presented in the Table 6.

4.3.1.1 Available Nitrogen

The available N status was significantly influenced by the cropping systems and the interaction effects of cropping systems and farming systems (Table 6). The mean values for available nitrogen ranged from 218.24 kg ha^{-1} to 272.20 kg ha^{-1}. The highest mean value was recorded in Coconut + Vegetable (272.20 kg ha^{-1}) cropping system, which was on par with Coconut + Banana (263.42 kg ha^{-1}) and the lowest mean value was observed in Coconut + Tuber (218.24 kg ha^{-1}) cropping system. Regarding the interaction effects, the mean values for available nitrogen status ranged from 173.09 kg ha^{-1} to 326.14 kg ha^{-1}. Conventional farming system of Coconut + Vegetable was found to have the highest mean value of 326.14 kg ha^{-1} which was on par with organic farming system of Coconut + Pepper (321.12 kg ha^{-1}) while the lowest available nitrogen was observed in conventional farming system of Coconut + Pepper (173.09 kg ha^{-1}) which was on par with organic farming system of Coconut + Tuber (175.58 kg ha^{-1}).

4.3.1.2 Available Phosphorus

The available P status of the soils of coconut based cropping systems was significantly influenced by the cropping systems and interactions, but the effect was non significant with respect to farming systems (Table 6). The mean values for available phosphorus ranged from 49.98 kg ha^{-1} to 77.78 kg ha^{-1}. The highest mean value was recorded in Coconut + Fodder (77.78 kg ha^{-1}) cropping system, which was on par with Coconut + Tuber (75.07 kg ha^{-1}) and Coconut + Vegetable (72.69 kg ha^{-1})

Table 6. Available nutrient status of the soils under coconut based cropping system-(AEU 9)

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
C_1	244.83	77.78	129.91	264.29	112.13
C_2	263.42	70.06	135.52	287.98	92.85
C_3	247.11	49.98	145.6	279.89	90.11
C_4	218.24	75.07	146.72	280.29	106.24
C_5	272.20	72.69	138.88	310.59	78.16
F_1	248.86	70.03	117.38	306.53	125.93
F_2	249.46	68.20	161.28	262.69	65.85
C_1F_1	260.91	91.87	116.48	294.69	137.85
C_2F_1	263.43	61.99	118.72	309.44	119.93
C_3F_1	321.12	49.64	118.72	303.26	127.05
C_4F_1	175.58	73.21	138.88	291.59	143.49
C_5F_1	218.26	73.45	94.08	333.66	101.32
C_1F_2	228.76	63.68	143.34	233.90	86.42
C_2F_2	258.40	78.13	152.32	266.52	65.78
C_3F_2	173.09	50.32	172.48	256.52	53.16
C_4F_2	260.89	76.93	154.56	269.00	68.99
C_5F_2	326.14	71.93	183.68	287.52	55.01
CD- C (0.05)	13.73	5.39	NS	18.96	5.72
CD- F (0.05)	NS	NS	6.81	11.99	3.62
CD- C F (0.05)	19.42	7.62	15.22	NS	8.08

NS: Non significant

C_1 - Coconut + Fodder grass
C_2 - Coconut + Banana
C_3 - Coconut + Pepper
C_4 - Coconut + Tuber
C_5 - Coconut + Vegetable

F_1 - Organic farming
F_2 - Conventional farming

cropping system, while the lowest mean value was observed in Coconut + Pepper (49.98 kg ha^{-1}) cropping system. Corresponding to the interaction effects, the mean values for available phosphorus ranged from 49.64 kg ha^{-1} to 91.87 kg ha^{-1}. The highest available phosphorus was noticed in organic farming system of Coconut + Fodder (91.87 kg ha^{-1}), while the lowest available phosphorus was recorded in organic farming system of Coconut + Pepper (49.64 kg ha^{-1}) which was on par with conventional farming system of Coconut + Pepper (50.32 kg ha^{-1}).

4.3.1.3 Available potassium

The statistical data analysis showed that the available potassium of the soils was significantly affected by the farming systems and interaction effects of cropping systems and farming systems, but the effect of cropping systems on available potassium was found to be non significant (Table 6). The mean values for available potassium in case of interaction effects ranged from 94.08 kg ha^{-1} to 183.68 kg ha^{-1}. The highest mean value of available potassium was noticed in conventional farming system of Coconut + Vegetable (183.68 kg ha^{-1}) which was on par with conventional farming system of Coconut + Pepper (172.48 kg ha^{-1}). The lowest available potassium was observed in organic farming system of Coconut + Vegetable (94.08 kg ha^{-1}). Even though the effect of cropping systems were non significant, the highest content was recorded in Coconut + Tuber cropping system (146.72 kg ha^{-1}).

4.3.1.4 Calcium

The effect of cropping systems and farming systems were found to be significant with respect to available calcium, but the interaction effects of cropping and farming systems was found to be non significant (Table 6). The mean values for available calcium ranged from 264.29 mg kg^{-1} to 310.59 mg kg^{-1}. The highest mean value was noticed in Coconut + Vegetable cropping system (310.59 mg kg^{-1}) and the lowest value was noticed in Coconut + Fodder cropping system (264.29 mg kg^{-1}) which was on par with Coconut + Pepper (279.89 mg kg^{-1}) and Coconut + Tuber cropping system (280.29 mg kg^{-1}). With regard to the interaction effects, the highest calcium content was noticed in organic farming system of Coconut + Vegetable (333.66 mg kg^{-1}), while the lowest calcium content was observed in conventional farming system of Coconut + Fodder (233.90 mg kg^{-1}).

4.3.1.5 Magnesium

The content of Magnesium was significantly influenced by the individual effects of cropping systems, farming systems and their interactions (Table 6). The mean values for available magnesium ranged from 90.11 mg kg^{-1} to 112.13 mg kg^{-1}. The highest mean value of 112.13 mg kg^{-1} was recorded in Coconut + Fodder cropping system which was on par with Coconut + Tuber cropping system (106.24 mg kg^{-1}) while the lowest mean value was noticed in Coconut + Vegetable cropping system (78.16 mg kg^{-1}). With respect to interaction effects, the mean values for available magnesium ranged from 53.16 mg kg^{-1} to 143.49 mg kg^{-1}. The highest mean value of 143.49 mg kg^{-1} was noticed in organic farming system of Coconut + Tuber cropping system which was on par with organic farming system of Coconut + Fodder (137.85 mg kg^{-1}) while the lowest mean value was recorded in conventional farming system of Coconut + Pepper (53.16 mg kg^{-1}) which was on par with Coconut + Vegetable (55.01 mg kg^{-1}).

4.3.2 Available micronutrient status

4.3.2.1 Iron

Statistical analysis of the data indicated that the available iron was significantly influenced by the cropping systems, farming systems and their interactions (Table 7). The mean values for available iron ranged from 20.05 mg kg^{-1} to 35.25 mg kg^{-1}. The highest available iron content was noticed in Coconut + Banana cropping system with mean value of 35.25 mg kg^{-1} and the lowest iron content was noticed in Coconut + Vegetable cropping system with mean value of

Table 7. Available micronutrient status of the soils under coconut based cropping systems-(AEU 9)

Treatments	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	B (mg kg^{-1})
C_1	25.79	0.93	12.71	3.22	1.11
C_2	35.25	1.26	15.66	3.64	1.08
C_3	23.67	1.02	9.57	1.91	1.19
C_4	23.13	1.00	7.89	1.82	0.91
C_5	20.05	1.27	8.41	1.55	0.63
F_1	31.46	1.35	15.55	3.62	0.83
F_2	19.69	0.84	6.15	1.23	1.14
C_1F_1	28.63	1.11	18.20	4.82	1.01
C_2F_1	45.19	1.64	23.29	5.74	1.08
C_3F_1	30.34	1.09	15.88	2.68	0.65
C_4F_1	28.18	1.31	10.79	2.63	0.80
C_5F_1	24.96	1.59	9.59	2.25	0.60
C_1F_2	22.94	0.74	7.23	1.61	1.22
C_2F_2	25.30	0.88	8.03	1.54	1.29
C_3F_2	17.00	0.95	3.26	1.14	1.50
C_4F_2	18.07	0.69	4.98	1	1.02
C_5F_2	15.14	0.96	7.24	0.84	0.66
CD- C (0.05)	2.60	0.16	2.74	0.65	0.10
CD- F (0.05)	1.65	0.10	1.73	0.41	0.06
CD- C F (0.05)	3.69	NS	3.87	0.92	0.14

NS: Non significant

C_1 - Coconut + Fodder grass
C_2 - Coconut + Banana
C_3 - Coconut + Pepper
C_4 - Coconut + Tuber
C_5 - Coconut + Vegetable

F_1 - Organic farming
F_2 - Conventional farming

20.05 mg kg^{-1}. With respect to interaction effects, the mean values for available iron ranged from 15.14 mg kg^{-1} to 45.19 mg kg^{-1}. The highest mean value of 45.19 mg kg^{-1} was noticed in organic farming system of Coconut + Banana and the lowest mean value of 15.14 mg kg^{-1} was observed in conventional farming system of Coconut + Vegetable.

4.3.2.2 Zinc

From Table 7, it was observed that cropping systems and farming systems were found to have significant effect on available zinc of the soils, but their interactions were found to be non significant. The mean values for available zinc ranged from 0.93 mg kg^{-1} to 1.27 mg kg^{-1}. The highest zinc content was noticed in Coconut + Vegetable cropping system with mean value of 1.27 mg kg^{-1} which was on par with Coconut + Banana (1.26 mg kg^{-1}) cropping system while the lowest zinc content was noticed in Coconut + Fodder cropping system with mean value of 0.93 mg kg^{-1} which was on par with Coconut + Pepper (1.02 mg kg^{-1}) and Coconut + Tuber (1 mg kg^{-1}) cropping system.

4.3.2.3 Manganese

The available manganese content in the soil was significantly influenced by the cropping systems, farming systems and their interactions (Table 7). The mean values for available manganese ranged from 7.89 mg kg^{-1} to 15.66 mg kg^{-1}. The highest mean value of 15.66 mg kg^{-1} was noticed in Coconut + Banana cropping system while the lowest mean value of 7.89 mg kg^{-1} was noticed in Coconut + Tuber cropping system. Regarding the effect of interactions, the mean values for available magnesium ranged from 3.26 mg kg^{-1} to 23.29 mg kg^{-1}. Organic farming system of Coconut + Banana recorded the highest mean value (23.29 mg kg^{-1}) and the conventional farming system of Coconut + Pepper recorded the lowest mean value (3.26 mg kg^{-1}).

4.3.2.4 Copper

The available copper content in the soil was significantly influenced by the cropping systems, farming systems and their interactions (Table 7). Mean values for available copper in cropping systems was ranged from 1.55 mg kg^{-1} to 3.64 mg kg^{-1}. The highest mean value 3.64 mg kg^{-1} was observed in Coconut + Banana cropping system which was on par with Coconut + Fodder (3.22 mg kg^{-1}) while the lowest mean value was noticed in Coconut + Vegetable (1.55 mg kg^{-1}) cropping system. Regarding the effect of interactions, the mean values for available copper ranged from 0.84 mg kg^{-1} to 5.74 mg kg^{-1}. The highest copper content was noticed in organic farming system of Coconut + Banana with a mean value 5.74 mg kg^{-1} which was on par with organic farming system of Coconut + Fodder (4.82 mg kg^{-1}) while the lowest copper content was recorded in conventional farming system of Coconut + Vegetable (0.84 mg kg^{-1}).

4.3.2.5 Boron

The Boron content in the soil was significantly influenced by the cropping systems, farming systems and their interactions (Table 7). Mean values of boron in cropping systems ranged from 0.63 mg kg^{-1} to 1.19 mg kg^{-1}. The highest mean value was observed in Coconut + Pepper (1.19 mg kg^{-1}) cropping system which was on par with Coconut + Fodder (1.11 mg kg^{-1}) while the lowest boron content was noticed in Coconut + Vegetable (0.63 mg kg^{-1}) cropping system. Regarding the interaction effects, mean values for boron ranged from 0.6 mg kg^{-1} to 1.5 mg kg^{-1}. The highest mean value 1.5 mg kg^{-1} was noticed in conventional farming system of Coconut + Pepper while the lowest mean value 0.6 mg kg^{-1} was observed in organic farming system of Coconut + Vegetable.

4.4 BIOLOGICAL PROPERTIES OF THE SOILS UNDER COCONUT BASED CROPPING SYSTEM

4.4.1 Enzyme Assay

4.4.1.1 Dehydrogenase

The results in Table 8 indicated that the dehydrogenase activity in the soil was significantly influenced by the cropping systems, farming systems and their interactions. Mean values for dehydrogenase activity in cropping systems ranged from 184.3 μg of TPF released g^{-1} of soil 24 h^{-1} to 326.92 μg of TPF released g^{-1} of soil 24 h^{-1}. The highest dehydrogenase activity was recorded in Coconut + Banana cropping system (326.92 μg of TPF released g^{-1} of soil 24 h^{-1}), while the lowest dehydrogenase activity was noticed in Coconut + Vegetable (184.3 μg of TPF released g^{-1} of soil 24 h^{-1}). With respect to interactions, mean values ranged from 101.25 μg of TPF released g^{-1} of soil 24 h^{-1} to 462.52 μg of TPF released g^{-1} of soil 24 h^{-1}. The highest mean value 462.52 μg of TPF released g^{-1} of soil 24 h^{-1} was noticed in organic farming system of Coconut + Banana while the lowest mean value 101.25 μg of TPF released g^{-1} of soil 24 h^{-1} was observed in conventional farming system of Coconut + Tuber .

4.4.1.2 Acid phosphatase

From the study, it is inferred that the acid phosphatase activity in the soil was significantly influenced by the cropping systems, farming systems and their interactions (Table 8). Mean values for acid phosphatase activity in cropping systems ranged from 42.19 μg of p-nitrophenol released g^{-1} of soil 24 h^{-1} to 56.23 μg of p-nitrophenol released g^{-1} of soil 24 h^{-1}. The highest mean value was observed in Coconut + Banana cropping system (56.23 μg of p-nitrophenol released g^{-1} of soil 24 h^{-1}) which was on par with Coconut + Fodder (52.44 μg of p-nitrophenol released g^{-1} of soil 24 h^{-1}) and Coconut + Tuber (55.95 μg of p-nitrophenol released g^{-1} of soil 24

Table 8. Enzyme activity in the soils under coconut based cropping systems-(AEU 9)

Treatments	Dehydrogenase (µg of TPF released g^{-1} of soil 24 h^{-1})	Acidphosphatase (µg of p nitro phenol released g^{-1} of soil 24 h^{-1})	β-glucosidase (µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4})	Protease (µM of amino nitrogen hydrolysed g^{-1} of soil h^{-1})	Catalase (% of H_2O_2 hydrolysed g^{-1} of soil h^{-1})	Amylase (µM of maltose g^{-1} of soil)
C_1	221.46	52.44	3.06	84.94	2.02	8.98
C_2	326.92	56.23	2.51	165.84	2.85	9.44
C_3	276.42	42.19	3.64	149.70	2.64	9.70
C_4	212.87	55.95	3.27	174.98	2.32	9.16
C_5	184.30	45.76	2.12	172.17	1.96	9.01
F_1	344.49	59.89	3.37	163.22	3.05	12.31
F_2	144.29	41.14	2.47	135.84	1.67	6.21
C_1F_1	311.83	56.00	3.51	99.34	2.54	9.80
C_2F_1	462.52	80.35	2.80	186.37	3.90	12.52
C_3F_1	368.38	47.26	4.10	161.46	3.54	13.82
C_4F_1	321.49	58.68	3.75	188.84	2.74	12.70
C_5F_1	258.22	57.13	2.72	180.07	2.52	12.70
C_1F_2	131.08	48.87	2.61	70.54	1.50	8.16
C_2F_2	191.32	32.11	2.23	145.32	1.80	6.36
C_3F_2	184.45	37.11	3.18	137.95	1.74	5.58
C_4F_2	101.25	53.20	2.79	161.11	1.90	5.62
C_5F_2	110.37	34.37	1.53	164.27	1.40	5.32
CD- C (0.05)	21.66	6.29	0.14	19.05	0.23	0.25
CD- F (0.05)	13.69	3.98	0.06	12.05	0.14	0.16
CD- C F(0.05)	30.63	8.91	0.14	NS	0.32	0.35

h^{-1}) cropping system. The lowest mean value was noticed in Coconut + Pepper cropping system (42.19 µg of p-nitrophenol released g^{-1} of soil 24 h^{-1}). Regarding interaction effects, mean values ranged from 32.11 µg of p-nitrophenol released g^{-1} of soil 24 h^{-1} to 80.35 µg of p-nitrophenol released g^{-1} of soil 24 h^{-1}. The highest value 80.35 µg of p-nitrophenol released g^{-1} of soil 24 h^{-1} was noticed in organic farming system of Coconut + Banana while the lowest mean value 32.11 µg of p-nitrophenol released g^{-1} of soil 24 h^{-1} was observed in conventional farming system of Coconut + Banana which was on par with conventional farming system of Coconut + Vegetable (34.37 µg of p-nitrophenol released g^{-1} of soil 24 h^{-1}) and Coconut + Pepper (37.11 µg of p-nitrophenol released g^{-1} of soil 24 h^{-1}).

4.4.1.3 β-glucosidase

From the Table 8, it is inferred that the β-glucosidase activity in the soil was significantly influenced by the cropping systems, farming systems and their interactions. Mean values for β-glucosidase activity in cropping systems ranged from 2.12 µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4} to 3.64 µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4}. The highest mean value was observed in Coconut + Pepper cropping system (3.64 µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4}) which was on par with Coconut + Tuber (3.27 µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4}) while the lowest mean value was noticed in Coconut + Vegetable (2.12 µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4}) which was on par with Coconut + Banana (2.51 µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4}). Regarding interaction effects, mean values for β-glucosidase activity ranged from 1.53 µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4} to 4.1 µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4}. The highest mean value 4.1 µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4} was noticed in organic farming system of Coconut + Pepper while the lowest mean value 1.53 µg pnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4} was observed in conventional farming system of Coconut + Vegetable.

4.4.1.4 Protease

From the Table 8, it is inferred that the protease activity in the soils was significantly influenced by the cropping systems and farming systems, but their interaction effects were found to be non significant. The mean values for protease activity in cropping systems ranged from 84.94 μM of amino nitrogen hydrolyzed g^{-1} of soil h^{-1} to 174.98 μM of amino nitrogen hydrolyzed g^{-1} of soil h^{-1}. The highest mean value was noticed in Coconut + Tuber cropping system (174.98 μM of amino nitrogen hydrolyzed g^{-1} of soil h^{-1}) which was on par with Coconut + Vegetable (172.17 μM of amino nitrogen hydrolyzed g^{-1} of soil h^{-1}) and the lowest protease activity was noticed in Coconut + Fodder (84.94 μM of amino nitrogen hydrolyzed g^{-1} of soil h^{-1}). Regarding interaction effects, the highest mean value of 188.84 μM of amino nitrogen hydrolyzed g^{-1} of soil h^{-1} was noticed in organic farming system of Coconut + Tuber while the lowest mean value 70.54 μM of amino nitrogen hydrolyzed g^{-1} of soil hr^{-1} was noticed in conventional farming system of Coconut + Fodder.

4.4.1.5 Catalase

From the Table 8, it is inferred that the catalase activity in the soils was significantly influenced by the cropping systems, farming systems and their interactions. Mean values for catalase activity in cropping systems ranged from 1.96 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1} to 2.85 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}. The highest catalase activity was observed in Coconut + Banana (2.85 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}) cropping system which was on par with Coconut + Pepper (2.64 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}) while the lowest activity of catalase was noticed in Coconut + Vegetable (1.96 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}) which was on par with Coconut + Fodder (2.02 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}). Regarding interaction effects, the mean values for catalase activity ranged from 1.40 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1} to 3.90 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}. The highest mean value 3.90 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1} was noticed in organic farming system of Coconut + Banana which was on par with organic farming system of Coconut + Pepper (3.54 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}), while the lowest mean value 1.40 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1} was recorded in conventional farming system of Coconut + Vegetable which was on par with conventional farming system of Coconut + Fodder (1.50 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}), Coconut + Banana (1.80 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}), Coconut + Pepper (1.74 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}) and Coconut + Tuber (1.90 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}).

4.4.1.6 Amylase

From the Table 8, it is inferred that the amylase activity in the soils was significantly influenced by the cropping systems, farming systems and their interactions. Mean values for amylase activity in cropping systems ranged from 8.98 μM of maltose g^{-1} of soil to 9.70 μM of maltose g^{-1} of soil. The highest mean value was noticed in Coconut + Pepper (9.70 μM of maltose g^{-1} of soil) cropping system and the lowest mean value was noticed in Coconut + Fodder (8.98 μM of maltose g^{-1} of soil) which was on par with Coconut + Tuber (9.16 μM of maltose g^{-1} of soil) and Coconut + Vegetable (9.01 μM of maltose g^{-1} of soil) cropping system. Regarding interaction effects, the mean values for amylase activity ranged from 5.32 μM of maltose g^{-1} of soil to 13.82 μM of maltose g^{-1} of soil. The highest mean value 13.82 μM of maltose g^{-1} of soil was noticed in organic farming system of Coconut + Pepper which was on par with organic farming system of Coconut + Banana (12.52 μM of maltose g^{-1} of soil) while the lowest mean value 5.32 μM of maltose g^{-1} of soil was recorded in conventional farming system of Coconut + Vegetable which was on par with conventional farming system of Coconut + Pepper (5.58 μM of maltose g^{-1} of soil) and Coconut + Tuber (5.62 μM of maltose g^{-1} of soil).

4.4.2 Microbial population of the soils under coconut based cropping system

4.4.2.1 Bacteria

Effect of treatments on bacterial population was significant, but the interaction effects was non significant (Table 9). The mean values for bacterial population of cropping systems ranged from 7.41 log cfu g^{-1} soil to 7.69 log cfu g^{-1} soil. The highest mean value was noticed in Coconut + Banana (7.69 log cfu g^{-1} soil) cropping system and the lowest mean value was noticed in Coconut + Tuber (7.41 log cfu g^{-1} soil) cropping system which was on par with Coconut + Fodder (7.43 log cfu g^{-1} soil), Coconut + Pepper (7.49 log cfu g^{-1} soil) and Coconut + Vegetable (7.49 log cfu g^{-1} soil).

4.4.2.2 Fungi

Effect of treatments on fungal population was significant with respect to cropping systems, farming systems and their interactions (Table 9). Mean values for fungal population of cropping systems ranged from 3.69 log cfu g^{-1} soil to 4.17 log cfu g^{-1} soil. The highest mean value was noticed in Coconut + Banana (4.17 log cfu g^{-1} soil) cropping system which was on par with Coconut + Tuber (4 log cfu g^{-1} soil) and Coconut + Vegetable cropping system (4.06 log cfu g^{-1} soil) while the lowest mean value was observed in Coconut + Fodder (3.69 log cfu g^{-1} soil) cropping system which was on par with Coconut + Pepper (3.99 log cfu g^{-1} soil). Regarding interaction effects, mean values for fungal population ranged from 2.91 log cfu g^{-1} soil to 4.57 log cfu g^{-1} soil. The highest mean value was noticed in organic farming of Coconut + Banana (4.57 log cfu g^{-1} soil) which was on par with conventional farming of Coconut + Banana (4.48 log cfu g^{-1} soil), Coconut + Pepper (4.56 log cfu g^{-1} soil), Coconut + Tuber (4.48 log cfu g^{-1} soil) and Coconut + Vegetable (4.39 log cfu g^{-1} soil) while the lowest mean value observed in conventional farming system of Coconut + Fodder (2.91 log cfu g^{-1} soil) which was on par with organic farming of Coconut + Fodder (3.78 log cfu g^{-1} soil), Coconut + Pepper (3.43 log cfu g^{-1} soil),

Table 9. Microbial population in the soils under coconut based cropping system (log cfu g^{-1} soil)-(AEU 9)

Treatments	Bacteria (10^{-6})	Fungi (10^{-3})	Actinomycetes (10^{-3})
C_1	7.43	3.69	4.09
C_2	7.69	4.17	4.03
C_3	7.49	3.99	3.51
C_4	7.41	4.00	4.02
C_5	7.49	4.06	3.76
F_1	7.98	3.48	4.19
F_2	7.03	4.49	3.58
C_1F_1	7.94	3.78	4.31
C_2F_1	8.04	4.57	4.30
C_3F_1	8.02	3.43	4.22
C_4F_1	7.96	3.53	4.14
C_5F_1	7.95	3.73	3.96
C_1F_2	6.93	2.91	3.86
C_2F_2	7.35	4.48	3.77
C_3F_2	6.97	4.56	2.80
C_4F_2	6.86	4.48	3.89
C_5F_2	7.03	4.39	3.56
CD- C (0.05)	0.12	0.20	0.16
CD- F (0.05)	0.07	0.13	0.10
CD- C F(0.05)	NS	0.28	0.22

NS: Non significant

C_1 - Coconut + Fodder grass
C_2 - Coconut + Banana
C_3 - Coconut + Pepper
C_4 - Coconut + Tuber
C_5 - Coconut + Vegetable

F_1 - Organic farming
F_2 - Conventional farming

Coconut + Tuber (3.53 log cfu g^{-1} soil) and Coconut + Vegetable (3.73 log cfu g^{-1} soil).

4.4.2.3 Actinomycetes

Effect of treatments with respect to cropping systems, farming systems and their interactions on actinomycetes population was significant (Table 9). Mean values for actinomycetes population of cropping systems ranged from 3.51 log cfu g^{-1} soil to 4.09 log cfu g^{-1} soil. The highest mean value was noticed in Coconut + Fodder cropping system (4.09 log cfu g^{-1} soil) which was on par with Coconut + Banana (4.03 log cfu g^{-1} soil) and Coconut + Tuber (4.02 log cfu g^{-1} soil) while the lowest actinomycetes population was noticed in Coconut + Pepper cropping system (3.51 log cfu g^{-1} soil) which was on par with Coconut + Vegetable (3.76 log cfu g^{-1} soil). Regarding interaction effects, the mean values for actinomycetes population ranged from 2.80 log cfu g^{-1} soil to 4.31 log cfu g^{-1} soil. The highest mean value was noticed in organic farming of Coconut + Fodder (4.31 log cfu g^{-1} soil), which was on par with organic farming of Coconut + Banana (4.30 log cfu g^{-1} soil), Coconut + Pepper (4.22 log cfu g^{-1} soil), Coconut + Tuber (4.14 log cfu g^{-1} soil) and Coconut + Vegetable (3.96 log cfu g^{-1} soil) while, the lowest value was noticed in conventional farming system of Coconut + Pepper (2.80 log cfu g^{-1} soil).

4.4.3 Biological fertility index

4.4.3.1 Enzyme activity number

Effect of treatments on enzyme activity number was significant with cropping systems, farming systems and their interactions (Table 10). Mean values for enzyme activity number of cropping systems ranged from 38.1 to 66.59. The highest mean value was noticed in Coconut + Banana cropping system (66.59) and the lowest enzyme activity number was observed in Coconut + Vegetable cropping system (38.1). Regarding interaction effects, mean values for enzyme activity number ranged

Table 10. Enzyme activity number (EAN) of the soils under coconut based cropping system-(AEU 9)

Treatments	EAN
C_1	45.13
C_2	66.59
C_3	56.39
C_4	43.85
C_5	38.10
F_1	70.19
F_2	29.83
C_1F_1	63.31
C_2F_1	94.01
C_3F_1	74.92
C_4F_1	65.69
C_5F_1	53.03
C_1F_2	26.95
C_2F_2	39.18
C_3F_2	37.87
C_4F_2	22.00
C_5F_2	23.17
CD- C (0.05)	4.33
CD- F (0.05)	2.74
CD- C F(0.05)	6.13

NS: Non significant

C_1 - Coconut + Fodder grass
C_2 - Coconut + Banana
C_3 - Coconut + Pepper
C_4 - Coconut + Tuber
C_5 - Coconut + Vegetable

F_1 - Organic farming
F_2 - Conventional farming

from 22 to 94.01. The highest mean value (94.01) was noticed in organic farming of Coconut + Banana and the second highest value was noticed in organic farming system of Coconut + Pepper (74.92), while the lowest mean value noticed in conventional farming system of Coconut + Tuber (22) which was on par with conventional farming of Coconut + Vegetable (23.17).

4.4.4 Enzyme Kinetics (*Michaelis – Menten Constant*) of the best cropping system

The system with highest value for Biological fertility Index (BFI) Coconut + Banana (Organic system) was selected for the incubation study. Table 11 and 12, presents the data obtained from determination of V_{max} and K_m at fortnightly intervals using various substrates for the enzymes urease, acid phosphatase and dehydrogenase.

From the Table 11 and 12, it was evident that the for enzyme urease, the mean values for V_{max} varied from 1.90 x 10^{-3} to 3.77 x 10^{-3} moles of urea hydrolyzed g^{-1} soil h^{-1}. The maximum value was reported at 8th week after incubation (3.77 x 10^{-3}) and the lowest at 12nd week (1.90 x 10^{-3} moles of urea hydrolyzed g^{-1} soil h^{-1}). The K_m values ranged from 0.95 x 10^{-3} to 2.50 x 10^{-3} moles of urea hydrolyzed g^{-1} soil h^{-1} with the highest value at 8th week after incubation (2.50 x 10^{-3} moles of urea hydrolyzed g^{-1} soil h^{-1}).

With respect to the enzyme acid phosphatase, the values for V_{max} varied between 7.90 x 10^{-3} to 19.80 x 10^{-3} μg of p-nitrophenol released g^{-1} soil h^{-1} with highest mean at 8th week after incubation (19.80 x 10^{-3} μg of p-nitrophenol released g^{-1} soil h^{-1}) and the K_m values varied from 3.95 x 10^{-3} to 9.90 x 10^{-3} μg of p-nitrophenol released g^{-1} soil h^{-1} and after 8th week of incubation the highest value was noticed (9.90 x 10^{-3} μg of p-nitrophenol released g^{-1} soil h^{-1}).

In the case of dehydrogenase enzyme, the values for V_{max} ranged from 7.56 x 10^{-3} to 16.21 x 10^{-3} μg of TPF released g^{-1} soil 24 h^{-1}. Among the mean values, the highest was noticed after 6th week of incubation (16.21 x 10^{-3} μg of TPF released g^{-1}

Table 11. Kinetic parameter (V_{max}) of the Coconut + Banana cropping system-(AEU 9)

Period	Vmax		
	Urease	Acid phosphatase	Dehydrogenase
2nd week	$2.60x10^{-3}$	$7.90x10^{-3}$	$13.21x10^{-3}$
4th week	$3.40x10^{-3}$	$10.90x10^{-3}$	$15.20x10^{-3}$
6th week	$3.77x10^{-3}$	$15.40x10^{-3}$	$16.21x10^{-3}$
8th week	$5.00x10^{-3}$	$19.80x10^{-3}$	$7.79x10^{-3}$
10th week	$3.44x10^{-3}$	$12.80x10^{-3}$	$15.06x10^{-3}$
12th week	$1.90x10^{-3}$	$18.40x10^{-3}$	$7.56x10^{-3}$

Urease : ppm of urea hydrolyzed g^{-1} soil h^{-1}

Acid phosphatase : µg of p nitro phenol released g^{-1} of soil 24 h^{-1}

Dehydrogenase : µg of TPF released g^{-1} of soil 24 h^{-1}

Table 12. Kinetic parameter (K_m) of the Coconut + Banana cropping system-(AEU 9)

Period	Km		
	Urease	Acid phosphatase	Dehydrogenase
2nd week	1.30x10^{-3}	3.95x10^{-3}	6.60x10^{-3}
4th week	1.70x10^{-3}	5.45x10^{-3}	7.60x10^{-3}
6th week	1.88x10^{-3}	7.70x10^{-3}	8.10x10^{-3}
8th week	2.50x10^{-3}	9.90x10^{-3}	3.89x10^{-3}
10th week	1.72x10^{-3}	6.40x10^{-3}	7.50x10^{-3}
12th week	0.95x10^{-3}	9.20x10^{-3}	3.78x10^{-3}

Urease : ppm of urea hydrolyzed g^{-1} soil h^{-1}

Acid phosphatase : µg of p nitro phenol released g^{-1} of soil 24 h^{-1}

Dehydrogenase : µg of TPF released g^{-1} of soil 24 h^{-1}

soil 24 h^{-1}) and the lowest at 12th week of incubation (7.56 x 10^{-3} µg of TPF released g^{-1} soil 24 h^{-1}). With respect to K_m values, the means ranged between 3.78 x 10^{-3} to 8.10 x 10^{-3} µg of TPF released g^{-1} soil 24 h^{-1} and after 6th week of incubation the highest value was noticed (8.10 x 10^{-3} µg of TPF released g^{-1} soil 24 h^{-1}).

4.5 MINERALIZATION OF SOIL NITROGEN

4.5.1 Total nitrogen

The interaction effect of treatments on total nitrogen was but non significant in case of cropping systems and farming systems (Table 13). Mean values for total nitrogen of cropping systems ranged from 0.17 % to 0.23 %. The highest mean value for interaction effects was noticed in organic farming of Coconut + Vegetable (0.31 %) which was on par with conventional farming of Coconut + Pepper (0.28 %), while the lowest mean value was noticed in conventional farming system of Coconut + Vegetable (0.10 %), which was on par with conventional farming system of Coconut + Fodder (0.13 %). Even though the cropping systems were found to be non significant, the highest mean value 0.23 % was noticed in Coconut + Pepper cropping system and the lowest total nitrogen was noticed in Coconut + Fodder (0.17 %) cropping system.

4.5.2 Mineralizable nitrogen

The interaction effect of treatments on mineralizable nitrogen was significant with cropping systems and farming systems, but non significant in case of interaction of cropping and farming systems (Table 13). Mean values of mineralizable nitrogen for cropping systems ranged from 181.20 mg kg^{-1} to 208.10 mg kg^{-1}. The highest mean value was noticed in Coconut + Vegetable (208.10 mg kg^{-1}) cropping system which was on par with Coconut + Tuber (198.80 mg kg^{-1}) cropping system while the lowest mean value was noticed in Coconut + Pepper (181.20 mg kg^{-1}) cropping system which was on par with Coconut + Fodder (183.70 mg kg^{-1}) and Coconut +

Table 13. Mineralization of soil nitrogen under the soils of coconut based cropping system- (AEU 9)

Treatments	Total N (%)	Microbial Biomass Nitrogen (μg N gm^{-1})	Mineralizable Nitrogen (mg kg^{-1})	% of mineralizable N to Total N	Microbial Nitrogen Quotient
C_1	0.17	80.83	183.70	10.71	0.05
C_2	0.21	85.05	185.00	8.75	0.04
C_3	0.23	77.28	181.20	10.11	0.04
C_4	0.21	81.25	198.80	10.22	0.04
C_5	0.21	85.60	208.10	10.90	0.05
F_1	0.22	87.99	262.80	12.41	0.04
F_2	0.19	76.01	119.92	7.87	0.06
C_1F_1	0.20	94.18	253.00	12.61	0.03
C_2F_1	0.23	95.00	264.00	11.81	0.03
C_3F_1	0.18	80.18	245.00	13.73	0.04
C_4F_1	0.18	85.64	270.00	8.94	0.04
C_5F_1	0.31	84.96	281.80	14.95	0.03
C_1F_2	0.13	67.48	114.40	8.81	0.07
C_2F_2	0.18	75.10	106.00	5.69	0.05
C_3F_2	0.28	74.38	117.40	6.48	0.04
C_4F_2	0.23	76.86	127.40	5.50	0.04
C_5F_2	0.10	86.24	134.40	12.87	0.08
CD- C (0.05)	NS	2.65	7.94	NS	0.007
CD- F (0.05)	NS	1.67	5.02	0.93	0.004
CD- C F(0.05)	0.09	3.74	NS	2.07	0.01

NS: Non significant

C_1 - Coconut + Fodder grass
C_2 - Coconut + Banana
C_3 - Coconut + Pepper
C_4 - Coconut + Tuber
C_5 - Coconut + Vegetable

F_1 - Organic farming
F_2 - Conventional farming

Banana (185.00 mg kg^{-1}) cropping system. Even though the interaction effects were found to be non significant, the highest mean value was recorded in organic farming of Coconut + Vegetable (281.80 mg kg^{-1}) and the lowest value noticed in conventional farming system of Coconut + Banana (106.00 mg kg^{-1}).

4.5.3 Microbial biomass nitrogen

Effect of treatments on microbial biomass nitrogen was significant with cropping systems, farming systems and their interactions (Table 13). Mean values for microbial biomass nitrogen of cropping systems ranged from 77.28 µg N g^{-1} to 85.60 µg N g^{-1}. The highest mean value was noticed in Coconut + Vegetable (85.60 µg N g^{-1}) which was on par with Coconut + Banana (85.05 µg N g^{-1}) cropping system and the lowest mean value was noticed in Coconut + Pepper (77.28 µg N g^{-1}) cropping system which was on par with Coconut + Fodder (80.83 µg N g^{-1}) and Coconut + Tuber (81.25 µg N g^{-1}) cropping system. Regarding interaction effects, the mean values for microbial biomass nitrogen ranged from 67.48 µg N g^{-1} to 95 µg N g^{-1}. The highest mean value 95.00 µg N g^{-1} was noticed in organic farming of Coconut + Banana which was on par with organic farming of Coconut + Fodder (94.18 µg N g^{-1}) while the lowest mean value of 67.48 µg N g^{-1} was observed in conventional farming system of Coconut + Fodder.

4.5.4 Percentage of mineralizable nitrogen to total nitrogen

From Table 13, it is observed that the effect of treatments on percentage of mineralizable nitrogen to total nitrogen was significant with respect to farming systems and their interaction with cropping systems, but cropping systems were found to be non significant. Regarding interaction effects, mean values ranged from 5.50 % to 14.95 %. The highest mean value (14.95 %) was noticed in organic farming of Coconut + Vegetable which was on par with organic farming system of Coconut + Pepper (13.73 %) while the lowest mean value 5.50 % was noticed in conventional farming system of Coconut + Tuber which was on par with conventional farming system of Coconut + Banana (5.69 %) and conventional farming system of Coconut + Pepper (6.48 %). Even though cropping systems was found to be non significant, the highest mean value was noticed in Coconut + Vegetable cropping system (10.90 %) while the lowest mean value was noticed in Coconut + Banana cropping system (8.75 %).

4.5.5 Microbial nitrogen quotient

Effect of treatments on microbial nitrogen quotient was significant with cropping systems, farming systems and their interactions (Table 13). The mean microbial nitrogen quotient of cropping systems ranged from 0.04 to 0.05. The highest mean value was noticed in Coconut + Fodder cropping system (0.05) and Coconut + Vegetable cropping system (0.05) while the lowest mean value was observed in Coconut + Banana (0.04), Coconut + Pepper (0.04) and Coconut + Tuber (0.04) cropping system. Regarding interaction effects, the mean values ranged from 0.03 to 0.08. The highest mean value 0.08 was noticed in conventional farming of Coconut + Vegetable which was on par with conventional farming of Coconut + Fodder (0.07) while the lowest mean value observed in organic farming system of Coconut + Fodder (0.03), Coconut + Banana (0.03) and Coconut + Vegetable (0.03).

4.6 MINERALIZATION OF SOIL CARBON

4.6.1 Organic carbon

Statistical analysis of the data indicated that the organic carbon status was significantly influenced by the cropping systems, farming systems and their interactions (Table 14). The mean values for cropping systems ranged from 0.87 % to 1.19 %. The highest organic carbon content was noticed in Coconut + Tuber (1.19 %) and the lowest organic carbon content was recorded in Coconut + Vegetable (0.87 %) cropping system. Regarding interaction effects, mean values for organic carbon status ranged from 0.68 % to 1.63 %. The highest mean value 1.63 % was noticed in

Table 14. Mineralization of carbon in the soils under coconut based cropping system-(AEU 9)

Treatments	Organic Carbon (%)	Water Soluble Carbon (mg kg^{-1})	Particulate Organic Carbon (%)	Microbial Biomass Carbon (mg of CO_2 g^{-1})
C_1	1.09	55.09	0.34	10.90
C_2	1.04	64.42	0.19	12.84
C_3	1.05	57.37	0.54	11.10
C_4	1.19	57.06	0.45	11.37
C_5	0.87	58.12	0.25	11.03
F_1	1.27	67.79	0.48	13.28
F_2	0.83	49.04	0.23	9.63
C_1F_1	1.28	61.75	0.55	11.63
C_2F_1	1.24	70.28	0.16	15.11
C_3F_1	1.12	61.64	0.65	12.84
C_4F_1	1.63	72.74	0.75	13.55
C_5F_1	1.05	72.52	0.25	13.26
C_1F_2	0.90	48.42	0.12	10.17
C_2F_2	0.83	58.55	0.23	10.56
C_3F_2	0.97	53.11	0.41	9.36
C_4F_2	0.76	41.38	0.14	9.24
C_5F_2	0.68	43.73	0.23	8.79
CD- C (0.05)	0.07	NS	0.12	0.78
CD- F (0.05)	0.05	2.69	0.08	0.49
CD- C F(0.05)	0.10	6.00	0.17	NS

NS: Non significant

C_1 - Coconut + Fodder grass
C_2 - Coconut + Banana
C_3 - Coconut + Pepper
C_4 - Coconut + Tuber
C_5 - Coconut + Vegetable

F_1 - Organic farming
F_2 - Conventional farming

organic farming of Coconut + Tuber and the lowest mean value 0.68 % noticed in conventional farming system of Coconut + Vegetable which was on par with Coconut + Tuber (0.76 %) under conventional farming system.

4.6.2 Water soluble carbon

Statistical analysis of the data indicated that the water soluble carbon (Table 14) was significantly influenced by the farming systems and their interaction with cropping systems, but non significant in case of cropping systems. The mean value for water soluble carbon of interaction effects ranged from 41.38 mg kg^{-1} to 72.74 mg kg^{-1}. The highest mean value 72.74 mg kg^{-1} was noticed in organic farming of Coconut + Tuber which was on par with organic farming system of Coconut + Banana (70.28 mg kg^{-1}) and Coconut + Vegetable (72.52 mg kg^{-1}), while the lowest mean value 41.38 mg kg^{-1} and 43.73 mg kg^{-1} were noticed in conventional farming of Coconut + Tuber and Coconut + Vegetable respectively. Even though the effect of cropping systems found to be non significant, the highest mean value was noticed in Coconut + Banana (64.42 mg kg^{-1}) and the lowest mean value was observed in Coconut + Fodder (55.09 mg kg^{-1}) cropping system.

4.6.3 Particulate organic carbon

Statistical analysis of the data indicated that the particulate organic carbon (Table 14) was significantly influenced by the cropping systems, farming systems and their interactions. The mean values for particulate organic carbon for cropping systems ranged from 0.19 % to 0.54 %. The highest value was noticed in Coconut + Pepper (0.54 %) which was on par with Coconut + Tuber (0.45 %) while the lowest mean value was recorded in Coconut + Banana (0.19 %) cropping system which was on par with Coconut + Vegetable (0.25 %). Regarding interaction effects, the mean values for particulate organic carbon ranged from 0.12 % to 0.75 %. The highest mean value 0.75 % was noticed in organic farming system of Coconut + Tuber and the lowest mean value of 0.12 % was noticed in Coconut + Fodder in conventional system which was on par with organic farming system of Coconut + Banana (0.16 %) and conventional farming system of Coconut + Tuber (0.14 %).

4.6.4 Microbial biomass carbon

Effect of treatments on microbial biomass carbon was significant with cropping systems, farming systems and non significant in case of interaction effects (Table 14). Mean value for microbial biomass carbon of cropping systems ranged from 10.90 mg of CO_2 g^{-1} to 12.84 mg of CO_2 g^{-1}. The highest mean value was noticed in Coconut + Banana (12.84 mg of CO_2 g^{-1}) and the lowest mean value was noticed in Coconut + Fodder (10.90 mg of CO_2 gm^{-1}) cropping system which was on par with Coconut + Pepper (11.10 mg of CO_2 g^{-1}), Coconut + Tuber (11.37 mg of CO_2 g^{-1}) and Coconut + Vegetable (11.03 mg of CO_2 g^{-1}). Even though interaction effects were found to be non significant, the highest mean value 15.11 mg of CO_2 g^{-1} was noticed in organic farming of Coconut + Banana and the lowest mean value 8.79 mg of CO_2 g^{-1} was recorded in conventional farming system of Coconut + Vegetable.

4.7 CORRELATION STUDIES

4.7.1 Correlation between micronutrients and soil enzyme activities of the soils of coconut based cropping systems AEU 9

The correlation matrix (Table 15) revealed a significant and positive correlation was noticed between dehydrogenase and Fe (r=0.913**), Zn (r=0.784*), Mn (r=0.892**) and Cu (r=0.870**). In the case of acid phosphatase also a positive correlation between Fe (r=0.791*), Zn (r=0.689*), Mn (0.723*), Cu (r=0.794*) and B (r=0.587*) was noticed. For protease, a positive correlation with Zn (r=0.591*) and B (r=0.575*), catalase with Fe (r=0.883**), Zn (r=0.728*), Mn (r=0.858**) and Cu (r=0.794*), amylase with Fe (r=0.738*), Zn (r=0.762*), Mn (0.703*) and Cu (r=0.643*).

Table 15. Correlation between micronutrient status and soil enzyme activities of the soils under coconut based cropping system - (AEU 9)

Treatments	Dehydrogenase	Acid phosphatase	Glucosidase	Protease	Catalase	Amylase	Fe	Zn	Mn	Cu	B
Dehydrogenase	1										
Acid Phosphatase	0.705*	1									
Glucosidase	0.590*	0.343	1								
Protease	0.379	0.297	0.034	1							
Catalase	0.954**	0.745*	0.604*	0.474	1						
Amylase	0.845**	0.664*	0.634*	0.360	0.855**	1					
Fe	0.913**	0.791*	0.370	0.261	0.883**	0.738*	1				
Zn	0.784*	0.689*	0.216	0.591*	0.728*	0.762*	0.694*	1			
Mn	0.892**	0.723*	0.370	0.170	0.858**	0.703*	0.910**	0.647*	1		
Cu	0.870**	0.794*	0.398	0.089	0.794*	0.643*	0.896**	0.669*	0.951**	1	
B	-0.343	0.587*	0.092	0.575*	-0.394	-0.460	-0.278	0.697*	-0.385	-0.349	1

* significant @ 5 %

4.7.2 Correlation between microbial load status and soil enzyme activities of the soils of coconut based cropping systems AEU 9

From the correlation matrix (Table 16), it was clear that a positive correlation exists between dehydrogenase and bacteria (r=0.907**), fungi (r=0.951**) and actinomycetes (r=0.607*). In the case of acid phosphatase, a significant positive correlation between fungi (r= 0.793*) and actinomycetes (r=0.659*), β-glucosidase with bacteria (r= 0.563*), catalase with bacteria (r=0.858**), fungi (r=0.957**) and actinomycetes (r=0.661*), amylase with bacteria (r=0.910**) , fungi (r=0.886**) and actinomycetes (r= 0.703*).

4.7.3 Correlation between micronutrient and soil enzyme activities of the best cropping system (organic farming system of Coconut + Banana)

It is noticed from the correlation matrix (Table 17) that catalase exhibits a positive correlation with amylase (r=0.954**). The enzyme activities *viz.,* dehydrogenase, acid phosphatase, β-glucosidase, protease, catalase and amylase exhibited negative correlation with micronutrients.

4.7.4 Correlation between microbial load status and soil enzyme activities of the best cropping system (organic farming system of Coconut + Banana)

The correlation matrix presented in Table 18, reveals a significant positive correlation between catalase and amylase (r=0.954**). Bacteria and fungi exhibits a positive correlation (r=0.967**). A negative correlation is noticed between the microbial load status and soil enzyme activities of the best cropping system.

Table 16. Correlation between microbial load (Bacteria, fungi and actinomycetes) status and soil enzyme activities of the soils under coconut based cropping system-(AEU 9)

Treatments	Dehydrogenase	Acid Phosphatase	Glucosidase	Protease	Catalase	Amylase	Bacteria	Fungi	Actinomycetes
Dehydrogenase	1								
Acid Phosphatase	0.705*	1							
Glucosidase	0.590*	0.343	1						
Protease	0.379	0.297	0.0345	1					
Catalase	0.954**	0.745*	0.604*	0.474	1				
Amylase	0.845**	0.664*	0.634*	0.360	0.855**	1			
Bacteria	0.907**	0.603	0.563*	0.408	0.858**	0.910**	1		
Fungi	0.951**	0.793*	-0.497	-0.517	0.957**	0.886**	0.911**	1	
Actinomycetes	0.607*	0.659*	0.344	0.132	0.661*	0.703*	0.707*	0.703*	1

* significant @ 5 %

Table 17. Correlation between micronutrient status and soil enzyme activities of the soils of Coconut + Banana (organic) system- (AEU 9)

Treatments	Dehydrogenase	Acid Phosphatase	Glucosidase	Protease	Catalase	Amylase	Fe	Zn	Mn	Cu
Dehydrogenase	1									
Acid Phosphatase	-0.170	1								
Glucosidase	0.0885	-0.558	1							
Protease	-0.144	-0.067	0.844	1						
Catalase	0.614	0.091	0.076	0.169	1					
Amylase	0.424	0.350	-0.085	0.160	0.954**	1				
Fe	0.641	0.269	0.185	0.184	0.147	0.084	1			
Mn	-0.168	0.476	-0.433	-0.354	-0.680	-0.572	0.426	1		
Zn	0.696	0.465	-0.492	-0.374	0.724	0.745	0.408	-0.044	1	
Cu	-0.416	0.109	-0.667	-0.744	-0.764	-0.680	-0.276	0.691	-0.224	1

* significant @ 5 %

Table 18. Correlation between microbial load (Bacteria, fungi and actinomycetes) status and soil enzyme activities of the soils of Coconut + Banana (organic) system-(AEU 9)

Treatments	Dehydrogenase	Acid Phosphatase	Glucosidase	Protease	Catalase	Amylase	Bacteria	Fungi	Actinomycetes
Dehydrogenase	1								
Acid Phosphatase	-0.170	1							
Glucosidase	0.088	-0.558	1						
Protease	-0.144	-0.067	0.844	1					
Catalase	0.614	0.091	0.076	0.169	1				
Amylase	0.424	0.350	-0.085	0.160	0.954**	1			
Bacteria	-0.067	-0.630	0.534	0.163	-0.676	-0.846	1		
Fungi	-0.296	-0.551	0.401	0.086	-0.828	-0.943	0.967*	1	
Actinomycetes	0.566	-0.584	0.731	0.514	0.654	0.438	0.0752	-0.129	1

* significant @ 5 %

Discussion

5. DISCUSSION

Coconut cultivation is one of the most efficient way of utilizing the natural resources *viz.,* land, air space and incident solar radiation. Being a widely spaced crop, it utilizes about 22 % of soil on area basis (Bavappa, 1990). High density multispecies cropping systems (HDMCS), is one of the approach which utilize the land efficiently with maximum profit.

Nutrient management in coconut based cropping system could be a complex task, as this involves the interplay of various factors *viz*., nutrient recycling, fertilizer addition, differential crop responses, nutrient uptake and soil environment. The balanced fertilization of major elements could be beneficial for the growth of plant above ground parts and roots. Farmers need to change their fertilization strategy that reflects their economic pressure and the nutrient supplementation remains a threat because of the escalating prices and their ill effect. Nutrient cycling in the soils also involve biochemical, chemical and physico-chemical reactions mediated by plant roots, micro organisms and soil animals. It is well known that all biochemical reactions are catalysed by enzymes, which are proteins specialized to perform biological reactions. With the increased extensive use of agricultural chemicals and appearance of industrial pollutants including pesticides considerable interest have been raised about the interaction of these chemicals in soils and soil enzymes. The activity of soil enzymes thus hold potential as soil quality indicators though they are sensitive to temporal changes due to environmental and management factors (Dick,1994). The present study will add to the theoretical corpus of soil enzymology. Hence the present study was carried out in the Department of Soil Science and Agricultural Chemistry, during 2015-17 to study the mineralization of soil nitrogen, carbon, kinetics and dynamics of enzymes under coconut based cropping systems in the mid laterite soils of AEU 9.

A brief interpretation of the results pertaining to the above study are furnished in the following paragraphs. 101

5.1. PHYSICAL PROPERTIES OF SOILS

The results on the soil properties revealed that bulk density, porosity and water holding capacity were significantly influenced by cropping system and farming system. With respect to the interaction effects, a significant difference was noticed in bulk density, water holding capacity but did not vary significantly in case of porosity.

In the case of bulk density, the lowest value was noticed in Coconut + Vegetable (main effects) and Coconut + Vegetable under organic farming situation. The highest value for bulk density was noticed in Coconut + Fodder under organic system of cultivation, which resulted in granulation of soil particles and thus lowering the bulk density. This might be due to the disturbance in the soil during vegetable cultivation. This finding corroborated with the findings of Logsdon and Cambardella (2000).

The highest water holding capacity in Coconut + Tuber (main effects) and Coconut + Tuber (under organic farming system) might be attributed to the highest organic carbon content in the soils under Coconut + Tuber. Due to bonding and negatively charged compounds present in organic material that bound together the soil particles and improve soil structure will help in higher water holding capacity. Also the presence of organic matter in soil reduces evaporation and transpiration thus increasing the water storage (Ebrahim *et al.*, 1998). Similar findings were reported by Bronic and Lal (2004).

From Table 4, it was observed that the highest value for porosity was noticed in Coconut + Pepper under organic system of management. The highest amount of particulate organic carbon content registered in this treatment might have contributed to the increased porosity under this treatment. The result corroborated with the findings of Miura *et al.* (2008).

5.2. ELECTROCHEMICAL PROPERTIES OF SOILS

pH is one of the important electrochemical property which decides the availability of nutrients, affects all physical, chemical and biological soil properties (Brady and Weil, 2002). In the study conducted on coconut based cropping system, a significant effect on pH due to farming situation and their interaction was noticed. It was also noticed that all the soils belonging to the coconut based cropping system under the study area fall under acidic category.

From Table 5, it was observed that a highest pH value of 5.33 was noticed in Coconut + Vegetable under organic farming situation and the lowest in Coconut + Fodder under conventional system. The lowest value might be due to the production of acidic root exudates by the crop. Slow decomposition of organic matter leading to accumulation of acids might have contributed to a lower pH (Andrews *et al.*, 2002). Moreover under conventional system of cultivation, application of inorganic fertilizers and limited application of liming materials might be have aggravated the pH of the soil. A moderating effect of organic residues applied in Coconut + Vegetable cropping system might have neutralized the acidity to some extent and therefore a pH value of 5.33 is noticed in Coconut + Vegetable cropping system. Similar results were reported by Mini *et al.* (2015) in a coconut based cropping system of Onattukara region. In the case of organic farming system, a higher pH value than the conventional system was noticed (Table 5). This might be due to the acid farming fertilizers added in conventional farming system. The organic acids produced in the organic farming system might be weak acids thereby does not contribute to a lower pH value and severe acidity.

Total accumulation of salts in soil is measured by electrical conductivity and from the present study it was observed that only the interaction between cropping and farming system had a significant effect (Table 5). The lowest value for EC is noticed in Coconut + Banana and Coconut + Pepper under conventional system of management, whereas, the highest value for EC is noticed in Coconut + Fodder under conventional system. Addition of fertilizer to the fodder crop for 103 stabilizing the yield might have increased the EC of the soil. Application of fertilizer salts might have increased the total soluble salt content of the soils. The ionic mobility observed per unit volume of saturation extract is usually high for soils receiving fertilizer treatments (Doolittle *et al.*, 1994). The possibility of lowest value of EC in the above mentioned system (Coconut + Banana and Coconut + Pepper) might be due to the washing/leaching out of salts either by irrigation water or by neutral sources. Similar results were reported by Chang *et al.* (1993).

5.3. AVAILABLE MAJOR NUTRIENT STATUS OF THE SOILS

Nitrogen is an important nutrient for crops and its application increases the growth and yield of crops. From the present study it was observed that the highest value for available nitrogen was recorded in Coconut + Vegetable under conventional farming situation and the lowest in Coconut + Pepper under conventional farming situation (Figure 1). In general the available nitrogen status between two farming situations were found to be non significant. One of the reason attributed to the increased available nitrogen in this treatment may be the highest percent of total nitrogen. Application of organic and inorganic nitrogen source in conventional system might have helped in mineralization of soil nitrogen leading to build up of available nitrogen content. This is in agreement with the findings of Sharma and Gupta, 1998. It is also believed that application of fertilizers in combination with manures might have favourably influenced the microorganisms, with the synthesis of higher microbial biomass, which release nitrogen upon mineralization (Banerjee *et al.*, 2006). In this treatment, receiving the combination of both organic and inorganic nitrogen sources maintain a higher level of available nitrogen consequent to a steady mineralization of organic manures coupled with a supplementary source from inorganic nitrogen fertilizer.

Phosphorus is an another important nutrient that plays a significant role in root growth, particularly development of lateral roots and fibrous roots (Brady and Weil, 2002). From Figure 1, it was observed that the available phosphorus content 104

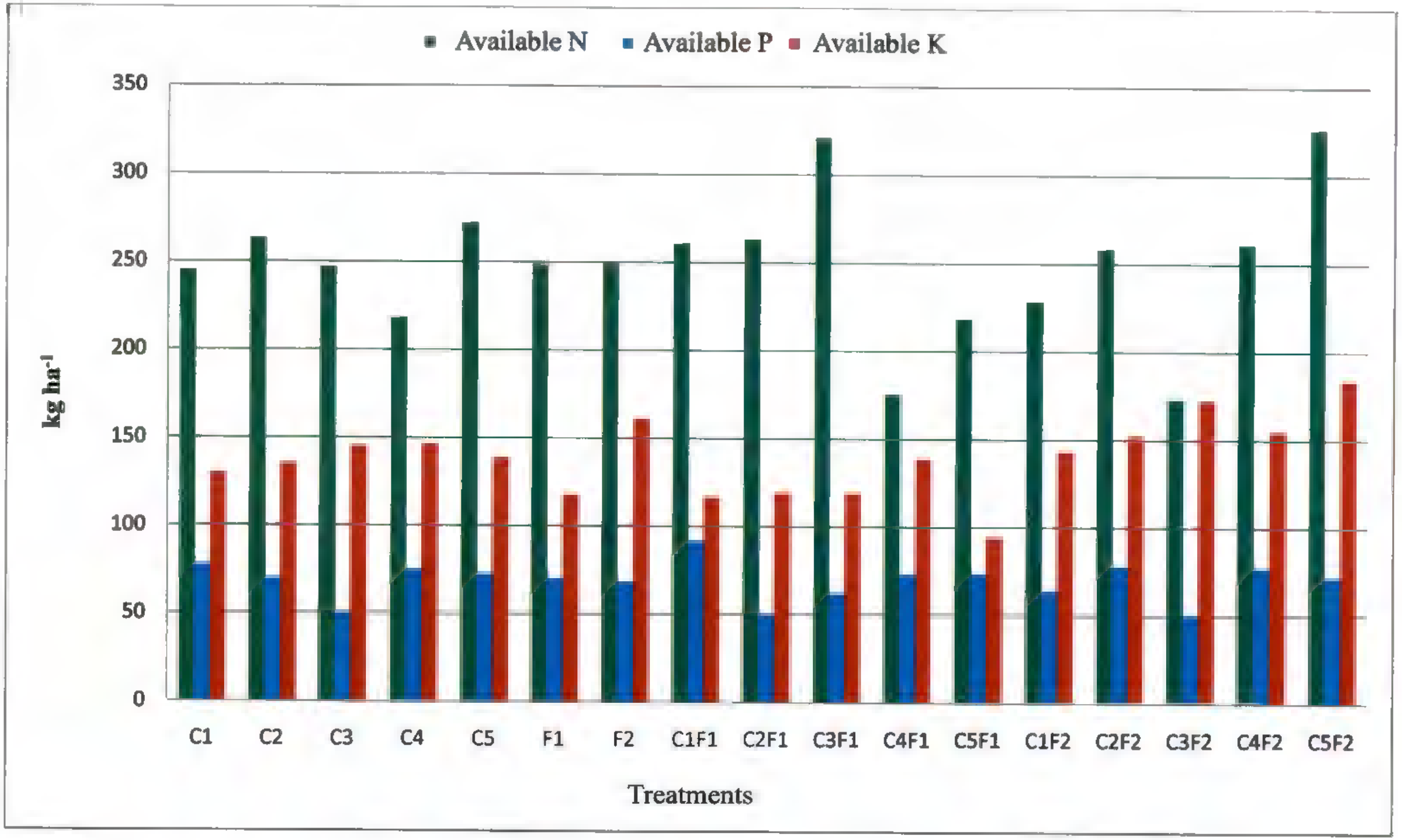

Figure 1. Major nutrient status (N, P and K) of the soils under coconut based cropping system-(AEU 9)

in the soil falls in the medium to high range. The highest value for available phosphorus is noticed in Coconut + Fodder under organic system of cultivation. This might have been due to the supplementation of phosphorus nutrients from the organic manures. Moreover the residue addition might have contributed to the production of organic acids resulting in the solublization of native phosphorus. The humic substances produced by root residues, the accelerated mineralization and phosphorus solubilisation effects of the system through favoured the level of soluble phosphorus in the soil. Lakshmi *et al.* (2007) also opined the same and reported that application of 150 kg P_2O_5 ha^{-1} significantly increased the available phosphorus status of the soil. Increase in available phosphorus status with the application of organic manures was also reported by Sharma *et al.* (2005).

Potassium is an element required for crops and imparting stress and resistance to the pest and diseases. The available potassium status of the experimental site belonged to low to medium. The 1:1 type of clay minerals dominated by kaolinite clay fraction have a poor retention capacity with respect to K^+ ion. The experimental site is dominated by oxidic materials of low activity clay which contributes very low K^+ ions. From the study it was inferred that the highest value for available potassium was noticed in Coconut + Vegetable under conventional system (Figure 1). The build up of soil available potassium might be due to the addition of potassium fertilizers and also due to the solubilisation action of certain organic acids produced. Kumar *et al.* (2007) also observed an increase in available potassium due to the applied fertilizers to a coconut based cropping system. The effect of cropping system on available potassium status was found to be non significant.

5.4. AVAILABLE SECONDARY NUTRIENT STATUS OF THE SOILS

The role of secondary nutrients *viz.*, calcium, magnesium and sulphur cannot be evicted and in crop growth play a significant role in metabolism.

Calcium is a vital component of cell wall and involved in metabolism and formation of cell nucleus. From the study conducted, it was inferred that the 106 available calcium and magnesium content were significantly influenced by treatments (Table 6). It was observed that the highest value for calcium is noticed under Coconut + Vegetable under organic farming situation. The highest value for pH under this treatment can be an attributing factor for the increased calcium. The low values reported for Coconut + Fodder under conventional farming might be due to the intense leaching of Ca^{2+} with the formation of ionic pairs NO_3, HCO_3^-, OH^-, Cl^- and SO_4^{2-} from mineral fertilizers. This is in accordance with the findings of Castro *et al.*, 2011.

Magnesium is a part of chlorophyll and aids in the formation of sugars, oils and fats. In the case of available magnesium as observed from Table 6, the highest value was noticed from Coconut + Tuber under organic system of cultivation. This might be attributed to the highest organic carbon status of the soil, which might have resulted in higher CEC there by higher magnesium content under this treatment. Similar results were reported by Lakshmi *et al.* (2007) in a coconut based cropping system.

5.5. AVAILABLE MICRONUTRIENT STATUS OF THE SOILS

Micronutrients are essential for plant growth and play an important role in balanced crop nutrition. Iron and manganese have been particular foci of studies on their solubilization by soil microflora, their availability to plants, and their effects on plant diseases. Manganese is a microelement required for diverse physiological functions in plants and plays a major role in both plant growth and disease resistance. Manganese can occur in several oxidation states, but it is available to plants only in the reduced form (Mn^{2+}). A lack of any one of the micronutrients in the soil can limit growth, even when all other nutrients are present in adequate amounts (Asad and Rafique, 2002).

From the study conducted, it was observed that cropping systems, farming situations and their interactions were found to impose significant effect on soil micronutrient status. From Figure 2, it was inferred that Coconut + Banana (organic system) recorded the highest value for available iron, manganese and 107

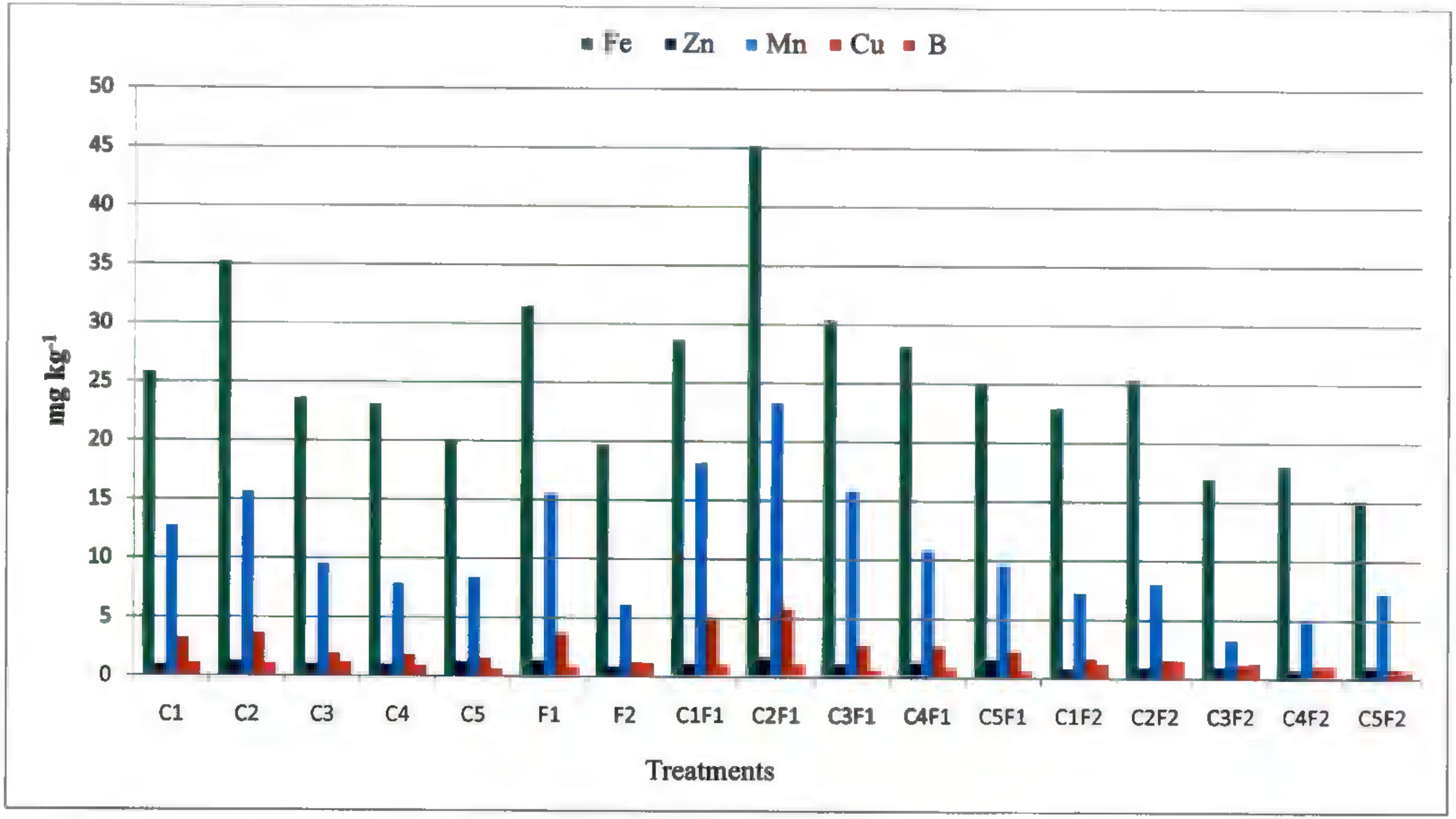

Figure 2. Micronutrient status (Fe, Zn, Mn, Cu and B) of the soils under coconut based cropping system-(AEU 9)

copper. This might be due to the addition of organic matter which complexes with micronutrients and thereby increasing micronutrient mobility. This is in agreement with the findings of Kadalli *et al.* (2000). The increase in the micronutrient status such as Fe, Mn and Cu with the application of enriched vermicomposts might be due to the improved soil characters and microbial activities as reported by Mortvedt (2010). The release of organic acids that both sequester cations and acidify the micro environment near roots is thought to be a major mechanism of solubilisation of Fe, Mn and Cu (Welch, 1995). The highest value for bacterial and fungal population in this treatment also supports the observed results.

In the case of available Zn and B, Coconut + Vegetable and Coconut + Pepper under organic system of management was found to record the highest values respectively. A wide range of mechanisms and chemical entities may be involved in the solubilization of different micronutrients. The root exudates under these crops have the ability to accelerate the oxidative dissolution of metallic zinc, releasing Zn^{2+}. In this case, the effect of the microbes may include the release of complexing ligands, which sequester Zn^{2+}, thereby increasing the dissolution of metallic zinc in the culture medium. Similar results were reported by Wei and Liu (2005). The highest value for particulate organic carbon registered under this treatment might have contributed to a highest value for boron. Greater boron adsorption capacity of the organic matter was due to high number of sorption sites. The formation of a complex between dihydroxy organic compounds and boron has been offered as an explanation for adsorption of boron on particulate organic carbon.

5.6. ENZYME STATUS OF THE SOILS

Soil is a living dynamic non renewable resource its conditions influence food production, environmental efficiency and global balance (Dick, 1997). A soil is biologically active, when the biological process proceed rapidly. Though various methods have been standardized to measure the biological activity, soil enzymatic activity assessing is only one way to measure the ecosystem status of the soil. Soil enzymes are mediators and catalysts of important soil functions that includes decomposition of organic inputs, transformation of native soil organic matter, release of inorganic nutrients for plant growth (Karaca *et al.,* 2002). In addition soil enzymes have a crucial role in C, N, P and S cycles. Thus the importance of soil enzymes have been explained as useful in describing and making prediction about ecosystem function, quality and interactions among the soil system (Dick and Tabatabai, 1992). Soil enzyme activities are very sensitive to both natural and anthropogenic disturbances and show a quick response to induced changes. Therefore soil enzyme activities can be considered effective indicators of soil quality resulting from environmental stress and management practices (Quilchano and Maranon, 2002).

In present investigation the activities of major soil enzymes *viz.,* Dehydrogenase, acid phosphatase, β-glucosidase, protease, catalase and amylase are assessed and the biological fertility of the soil is evaluated by calculating the Enzyme Activity Number.

5.6.1. Dehydrogenase

Dehydrogenase is an enzyme that oxidises soil organic matter by transferring protons and electrons from substrate to acceptors. This enzyme is considered to exist as an integral part of intact cells but do not accumulate extracellularly in the soil (Das and Varma, 2011). Burns (1982) reported that the dehydrogenase enzyme activity is commonly used as an indicator of biological activity in soil. Soil dehydrogenase activity is a function of soil management system as it directly or indirectly influenced by management system (Chu *et al.,* 2007).

From the study, it was noticed that the organic system of cultivation had a significant influence on dehydrogenase activity than the conventional system. Organic system of cultivation might have contributed to the spurt of microbial population in the soil especially bacteria thus resulting in higher dehydrogenase

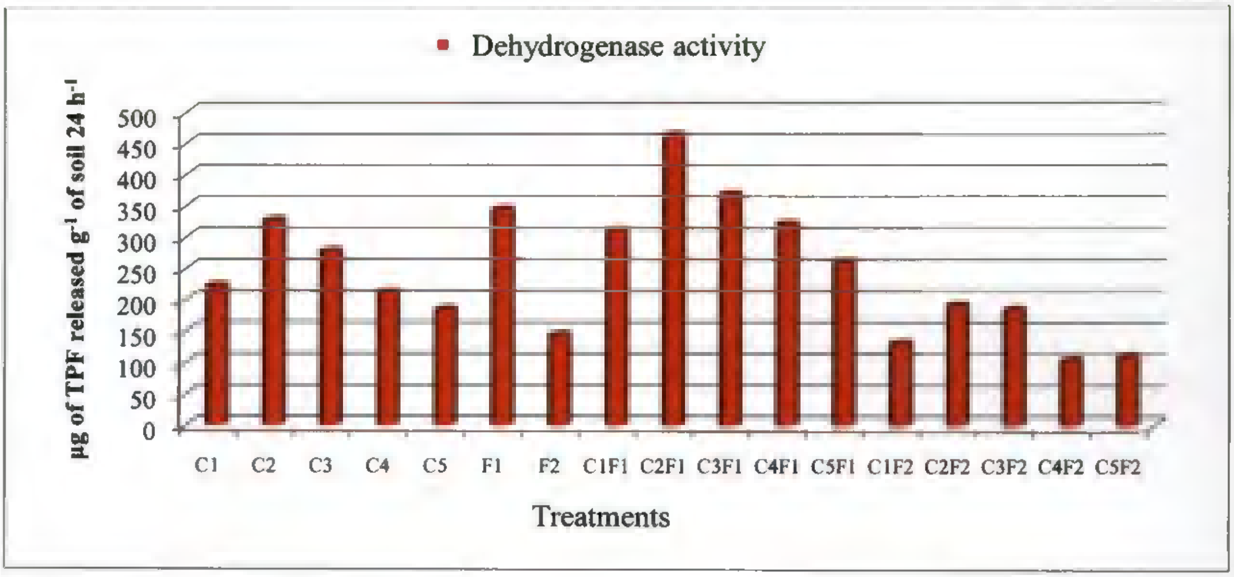

Figure 3. Dehydrogenase activity of the soils under coconut based cropping system-(AEU 9)

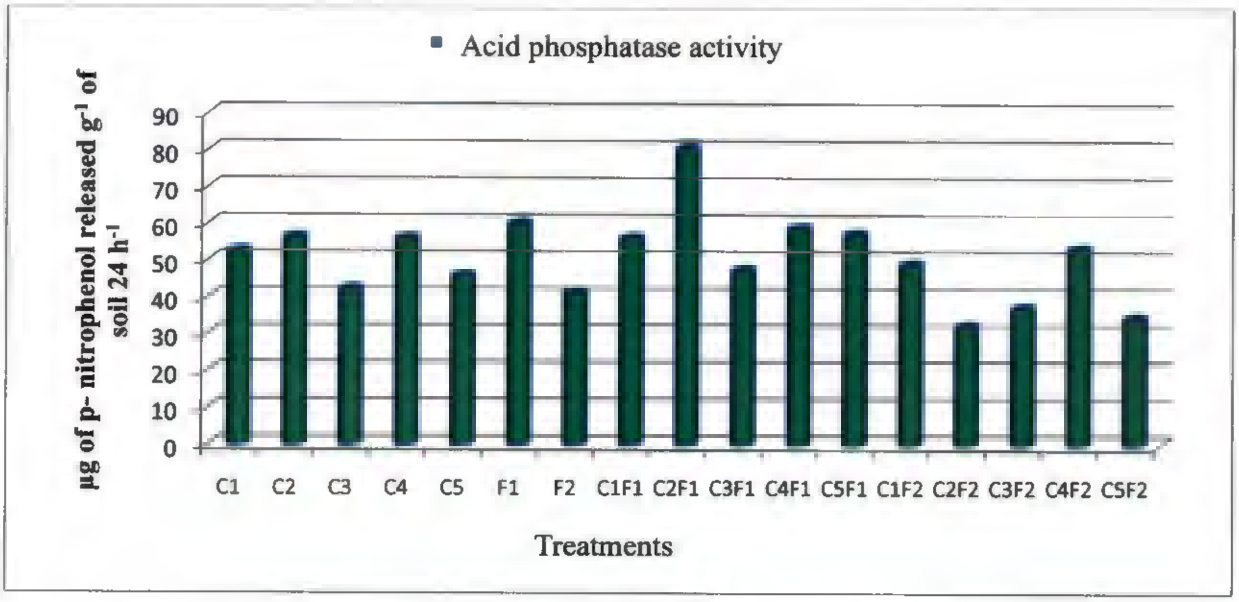

Figure 4. Acid phosphatase activity of the soils under coconut based cropping system-(AEU 9)

activity. This might be also due to organic residues added to the soil which provide carbon and energy to the soil microbes resulting into multiplication of microbial population and increase in dehydrogenase activity (Geethakumari and Shivashankar, 1991). Similar increase in dehydrogenase activity with the addition of FYM /vermicompost was reported by Walls-Thumma (2000).

With respect to the main effects, Coconut + Banana was observed to be the best cropping system with respect to soil dehydrogenase activity. The results suggest that increased dehydrogenase activity under Coconut + Banana might have been due to stimulation of microbial activity by the root exudates of the intercrop (Dick, 1994).

A highly significant and positive correlation with Fe (r= 0.913*), Zn (r= 0.784*), Mn (r= 0.892**), Cu (r= 0.870**), bacteria (r= 0.907**), fungi (r= 0.951**) and actinomycetes (r= 0.913**) also supports this result. From the Figure 3, it is also noticed that the bacterial count in Coconut + Banana system was the highest thus supporting the highest dehydrogenase activity. The results corroborated with the findings of Albiach *et al.* (2001), who reported an increasing in dehydrogenase activity with the addition of organic matter. Dehydrogenase activity with the application of organic sources might be linked to more substrate availability in soil (Basak *et al.*, 2013).

This reflects greater biological activity in soil and the stabilization of extracellular enzymes through complexation with humic substances. Hence Coconut + Banana under organic system of cultivation was found to be the best treatment with regard to dehydrogenase activity.

5.6.2. Acid phosphatase

Organic phosphorus is abundant in soil and can contribute to the P nutrition of plants and microbes following hydrolysis and release of free phosphate. This process is catalysed by phosphatase enzyme which are actively secreted into soil (Miller *et al.*, 2001). P compounds in soil are generally 112 mineralized by enzymes, collectively called "Phosphatases" that catalyzes the hydrolysis of esters and anhydrides of phosphoric acid (Makoi *et al*., 2010). Acid phosphatase is a group of enzymes which catalyse the hydrolyte cleavage of C-O-P ester bond. Phosphorus in soil release phosphorus as plant available inorganic form (Yadav and Tarafdar, 2001).

From the Figure 4, it is noticed that Coconut + Banana recorded the highest value for acid phosphatase activity which was on par with Coconut + Fodder and Coconut + Tuber cropping system. The highest activity of acid phosphatase noticed in these treatments might be attributed to the low available P status. Whenever there is a signal indicating P deficiency in the soil, acid phosphatase secreation from plant roots is increased to enhance the solubilisation and remobilization of PO_4 thus influencing the ability to cope with P stressed condition. These observations are similar with the findings of Versaw and Harrison (2002).

In the case of interaction effects, the highest value was noticed for Coconut + Banana under organic management, while the lowest in the conventional system of Coconut + Banana. The highest activity observed in the aforesaid treatment might be also due to the protection of phosphatase enzyme produced by the adsorption and stabilization mechanism brought about by a higher level of organic colloids in this system.

A significant and positive correlation between acid phosphatase and micronutrients noticed *viz*., Fe (r=0.719*), Zn (r=0.689*), Mn (r=0.723*), Cu (r=0.794*) and B (r=0.587*) might have contributed to the increased phosphatase activity under this treatment.

The role of pH cannot be evicted as it influences the interaction between enzymes and matrices (Ohmura and Hayano, 1986). It has been suggested that either the rate of synthesis or release of phosphatase by soil microbes is related to soil pH and from the study it was observed a significant positive correlation.

5.6.3. β-glucosidase

β-glucosidase is a common and predominant enzyme in soil and it is involved in catalysing the hydrolysis of various β-glucosidases present in plant debris decomposing into soil ecosystem (Martinez and Tabatabai, 1997). It is a rate limiting enzyme in microbial degradation of cellulose to glucose, an important C energy source of life for microorganisms in the soil (Esen, 1993).

From the Figure 5, it was noticed that a significant effect was noticed on β-glucosidase activity. The highest β-glucosidase activity was noticed in Coconut + Pepper and Coconut + Tuber cropping system. In general the organic system of cultivation was found to be favourable for the activity of β-glucosidase. The highest value reported here showed that the activity of β-glucosidase was influenced directly by the organic carbon content (1.19 %) for Coconut + Tuber and Coconut + Pepper (1.05 %). This is also supported by the results showing that microbial growth favouring the release of β-glucosidase in this kind of environment (Dick, 1994). Similar trend was observed in the interaction effect of Coconut + Pepper under organic system of cultivation thereby a significant increase in enzyme activity after the addition of FYM was noticed by Kizilkay and Bayark (1998).

5.6.4. Protease

Proteases are ubiquitous and originate from a number of different sources in soil including microorganisms (bacteria, fungi and actinomycetes), plants and animal excrements (Vranova *et al.,* 2013). Many of these enzymes are extracellular, as large number of native proteins are too large to be observed by living cells (Jan *et al.,* 2009). Proteolysis is an important process in many ecosystem with regard to N cycling because it is considered to be the rate limiting step during N mineralization.

From the Figure 6, it was noticed that the highest activity of protease in Coconut + Tuber cropping system was recorded, which was similar to Coconut + 114

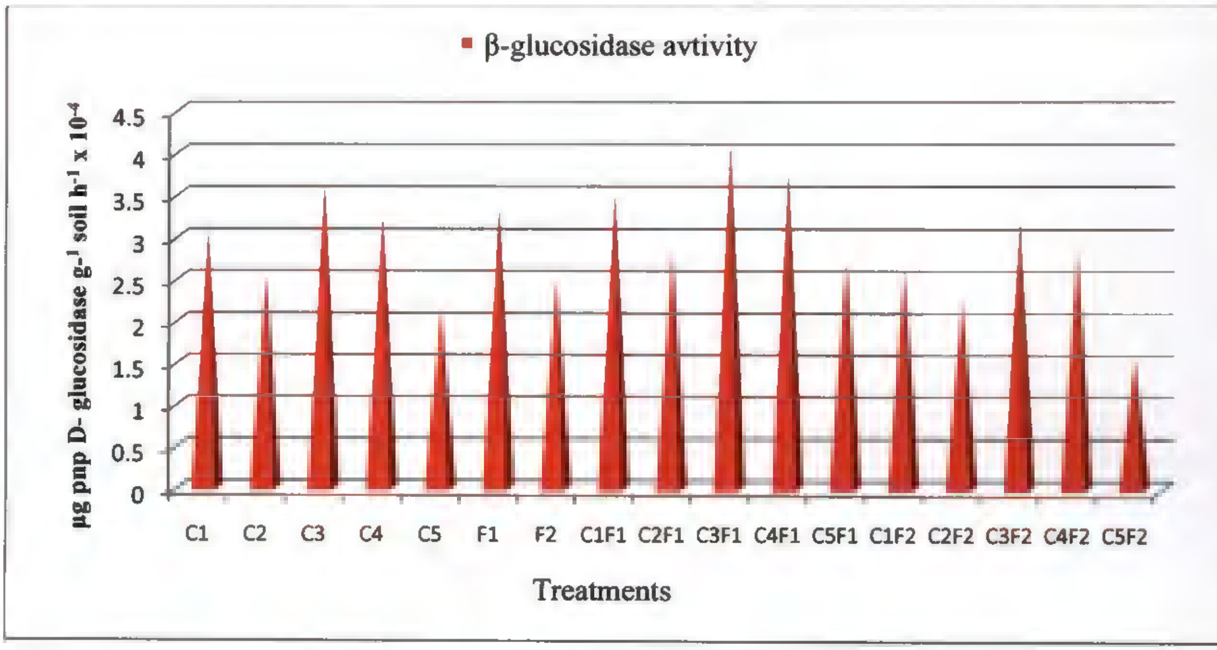

Figure 5. β-glucosidase activity of the soils under coconut based cropping system-(AEU 9)

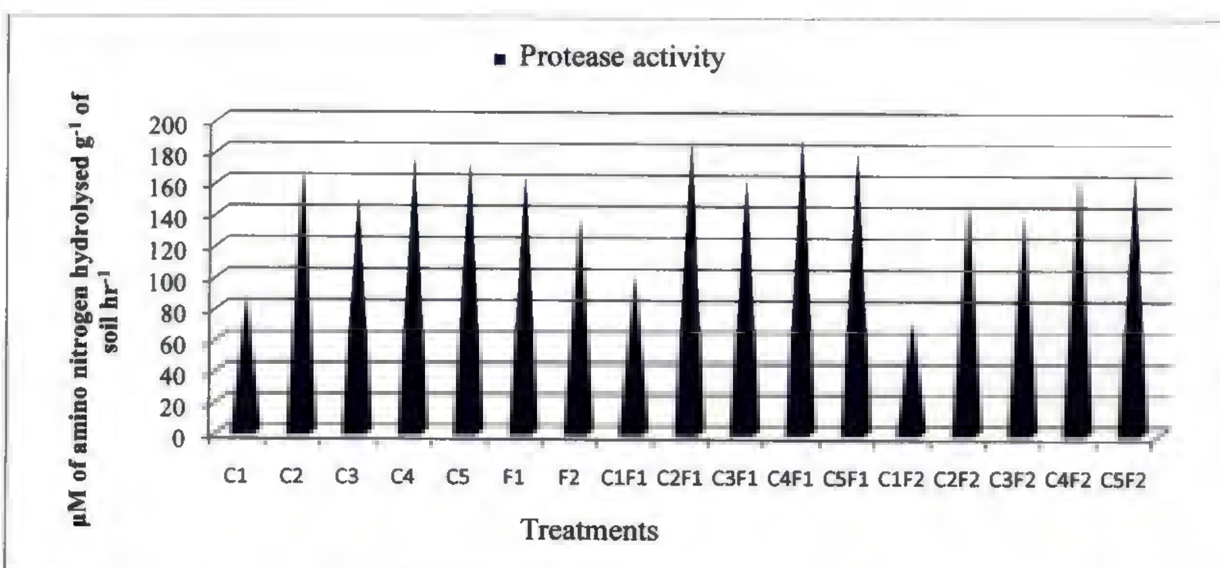

Figure 6. Protease activity of the soils under coconut based cropping system-(AEU 9)

Vegetable in case of main effects. In the case of interaction also, Coconut + Tuber under organic system recorded the highest value for protease activity. The highest activity of protease in this treatment may be attributed to the highest status of available potassium, mineralizable nitrogen, organic carbon and water holding capacity. These results are in accordance with the findings of Rajashekararao and Siddaramappa (2008).

The availability of mineralizable nitrogen as a potential substrate source might have triggered the production of protease enzymes thereby reflecting on higher activity (Aon *et al.,* 2001). Organic carbon content of particular treatment is the highest with respect to main effect, thereby it acts as a carbon source for the microbes to act upon and thereby increasing the population of proteolytic bacteria, resulting in highest protease activity.

A significant positive correlation of protease activity with micronutrients like Zn (r= 0.591*) and boron (r= 0.575*). The highest protease activity under organically treated plots might be due to the amounting biomass derived from the lysis of the active cells which contributes a reserve of substrate protein in soil for the proteolytic microflora to proliferate thus expressing a higher protease activity (Watanabe and Hayano, 1993).

5.6.5. Catalase

Catalase (hydrogen-peroxide oxidoreductase, EC 1.11.1.6) is an intracellular enzyme found in all aerobic bacteria and most facultative anaerobes, but absent from obligate anaerobes (Alef and Nannipieri, 1995). Catalase activity in soils is considered an indicator of aerobic microbial activity and has been related to both the number of aerobic microorganisms and soil fertility. The highest catalase activity was observed in Coconut + Banana (2.85 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}) cropping system, which was on par with Coconut + Pepper (2.64 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1}) while, the lowest activity of catalase was noticed in Coconut + Vegetable.

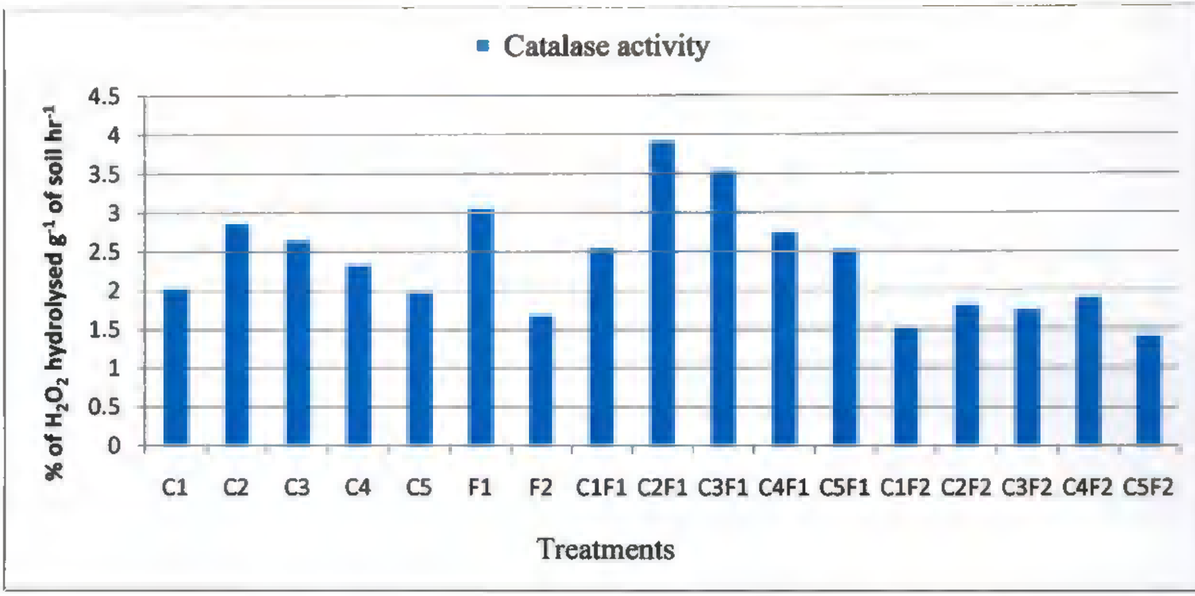

Figure 7. Catalase activity of the soils under coconut based cropping system-(AEU 9)

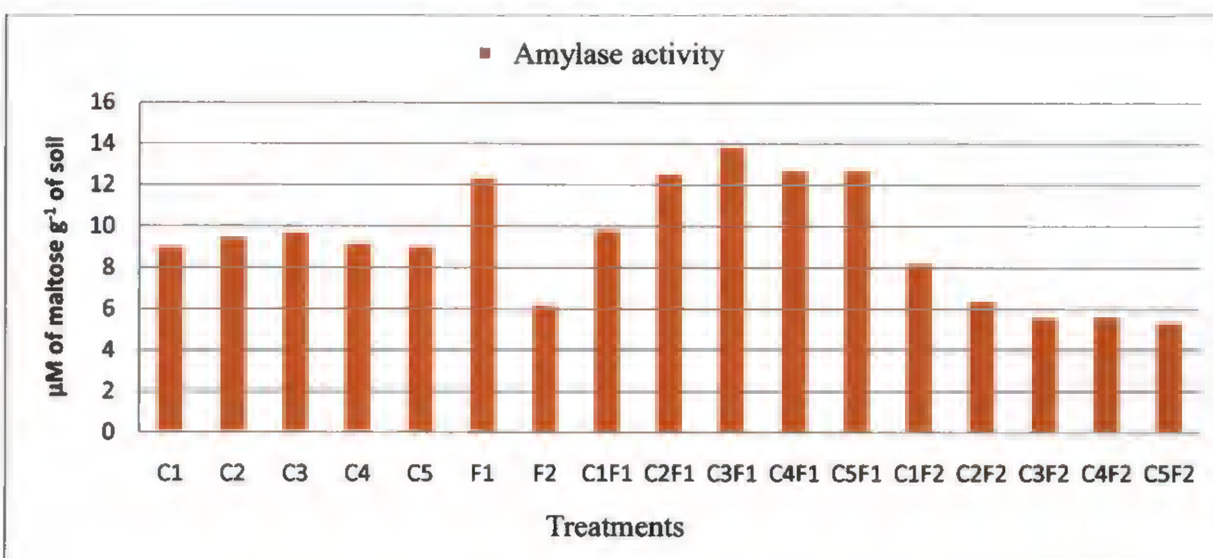

Figure 8. Amylase activity of the soils under coconut based cropping system-(AEU 9)

The highest activity was noticed in organic farming situation than the conventional system of cultivation. Some studies have reported that soils in organic farming regimes had higher microbial functional diversity than those in conventional farming systems. According to some investigators, the bacterial diversity was always higher in manure/ farmyard manure treated soils regardless of land use patterns. Although fertilization has resulted in increases in crop yield, this application was not sufficient in triggering a significant improvement in the soil microbial properties and activities of enzymes such as catalase (Zhang *et al.*, 2012).

Regarding interaction effects, the highest mean value 3.9 % of H_2O_2 hydrolyzed g^{-1} of soil h^{-1} was also noticed in organic farming system of Coconut + Banana . The highest catalase activity reported might be due to the availability of substrate (Water soluble carbon and microbial biomass carbon) for the microbes to act upon with the release of catalase enzyme. The results are in conformity with the findings of Trevors, 1984 .The highest population of microflora (bacteria and fungi) reported under this treatment serve as one of the factor for the increased catalase activity (Figure 7).

5.6.6. Amylase

Amylases together with invertases and cellulases form the group of enzymes that are responsible for the rate and source of decomposition of plant materials in soil. Amylase is the name of starch hydrolyzing enzyme in which the most important is α-amylase which converts starch to glucose or oligosaccharides (Thoma *et al.*, 1971).

From the investigation carried out, it was observed that the highest activity of amylase 13.82 µM of maltose g^{-1} of soil was reported in Coconut + Pepper under organic system of management(Figure 8). Significant differences among all treatments suggest that organic system of cultivation had a considerable positive effect on size and activity of microbial community thereby increasing the amylase activity.

The highest activity in this treatment might be due to the highest particulate organic carbon and total nitrogen content reported in that treatment. Particulate organic carbon serves as carbon source there by amylase secreting microbes respond positively which helps to enhance enzyme production (Sur *et al.*, 2003). Griffiths *et al.* (1999) observed similar trends while studying the effect of varying rates of carbon substrates on amylase activity.

A significant and positive correlation with Fe (r=0.738*), Zn (r=0.762*), Mn (r=0.703*), Cu (r=0.643*), bacteria (r=0.910**), fungi (r=0.886**) and actinomycetes (r=0.703*) also substantiates the observed results.

5.7. MICROBIAL POPULATION OF THE SOILS

Microbial and biochemical properties of soil have been proposed as early and sensitive indicators of soil ecosystem. Microbes *viz.,* bacteria, fungi and actinomycetes play a significant role in the improvement of soil health and quality through decomposition and transformation of organic matter (Mullings and Parish, 1984).

Microbes also play a key role in nutrient cycling for sustaining the productivity of the soils, because they are the source and sink for mineral nutrition and can carry out biochemical transformation (Jenkinson and Ladd, 1981).

The agricultural management practices were observed to influence the microbial community in an coconut based cropping system. Altogether from the study, results suggest a functional redundancy of the microbial communities of organically and conventionally managed crops in a coconut based cropping system.

From the Figure 9, it is observed that Coconut + Banana under organic system of cultivation reported the highest values for bacteria and fungi. The highest value for microbial biomass carbon of 15.11 mg CO_2 g^{-1} of soil reported in organic farming system of Coconut + Banana might be the contributing factor

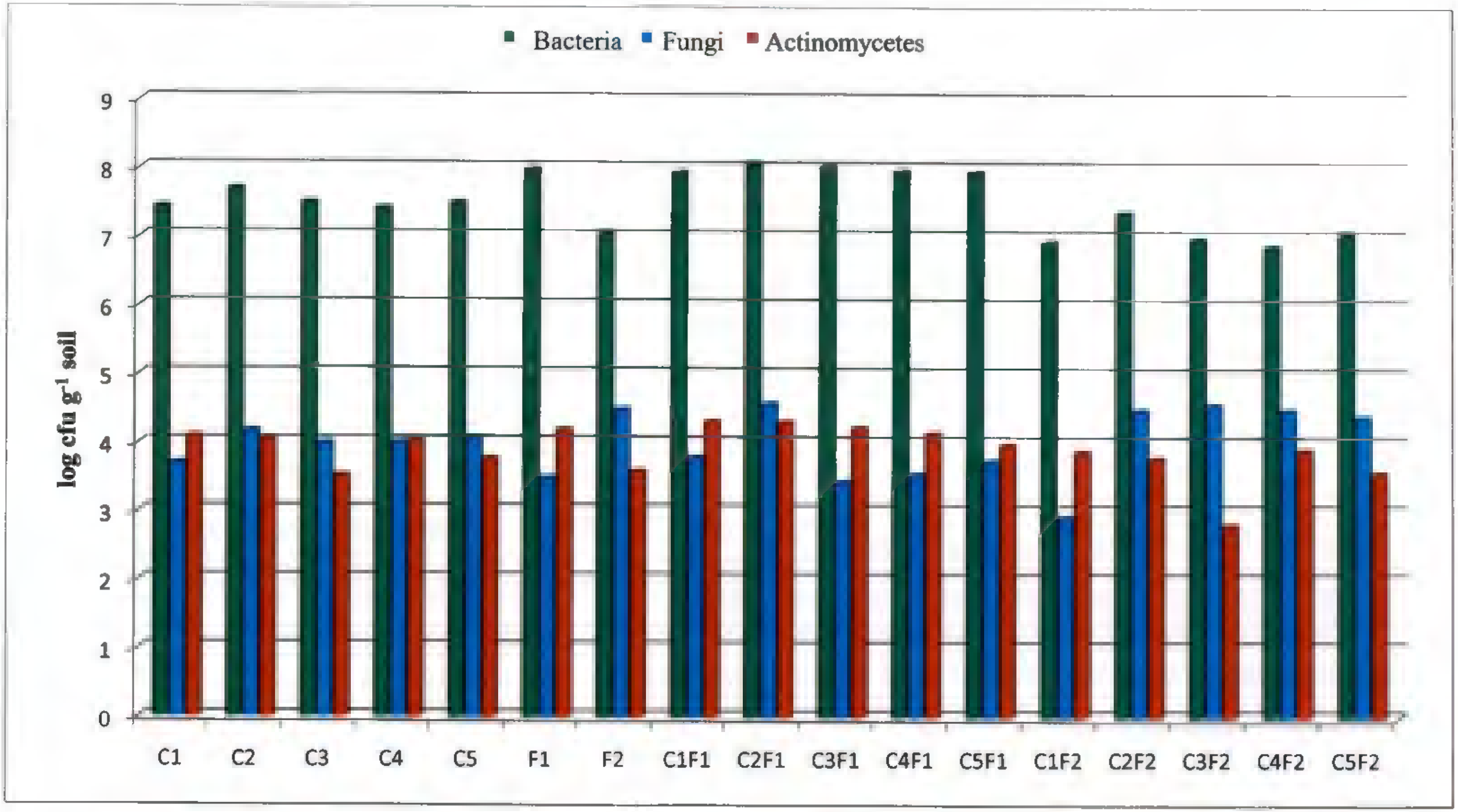

Figure 9. Microbial population of the soils under coconut based cropping system-(AEU 9)

for the increased bacterial and fungal population. The treatments with high water soluble carbon and microbial biomass carbon might have favoured the microbial growth. Similar results were reported by Rekhi *et al.* (2002). In general, on comparing both conventional and organic farming system, the highest population was noticed in the organic system. Similar results were reported by Asakawa and Kimura (2008), who reported that organic management practices may lead to increased soil microbial biomass activity and diversity.

The lowest value for bacterial count (Coconut + Tuber), fungal count (Coconut + Fodder) and actinomycetes count (Coconut + Pepper) might be attributed to the varied factors that influence the multiplication rates (Bai *et al.*, 2010).

5.8. ENZYME ACTIVITY NUMBER - INDEX OF BIOLOGICAL FERTILITY

Soil enzymes have been reported as useful soil biological indicators due to their relationship to soil biology being operational practical, sensitive, integrative and easy to measure and described as "Biological fingerprints" (Bandick and Dick, 1999). In general, from the study it was observed that the organic system of management recorded the highest value of enzyme activity number than the conventional system. The long term effect of organic amendments on enzyme activities is probably the combined effect of a higher degree of the stabilization of enzyme to humic substances and an increase in the microbial biomass with an increased concentration (Crecchio, 2001). Similar results was observed by Tejada *et al.* 2008.

With regard to the Enzyme Activity Number as proposed by Beck (1984), from Figure 10, it was observed that the highest activity was noticed in Coconut + Banana (main effect), Coconut + Banana under organic system of cultivation.

It is obvious from the study, the highest values for dehydrogense (462.52 µg of TPF released g^{-1} of soil 24 h^{-1}), acid phosphatase (80.35µg of p-nitrophenol released g^{-1} of soil 24 h^{-1}) and catalase (3.9 % of H_2O_2 hydrolysed g^{-1} of soil hr^{-1}) 121

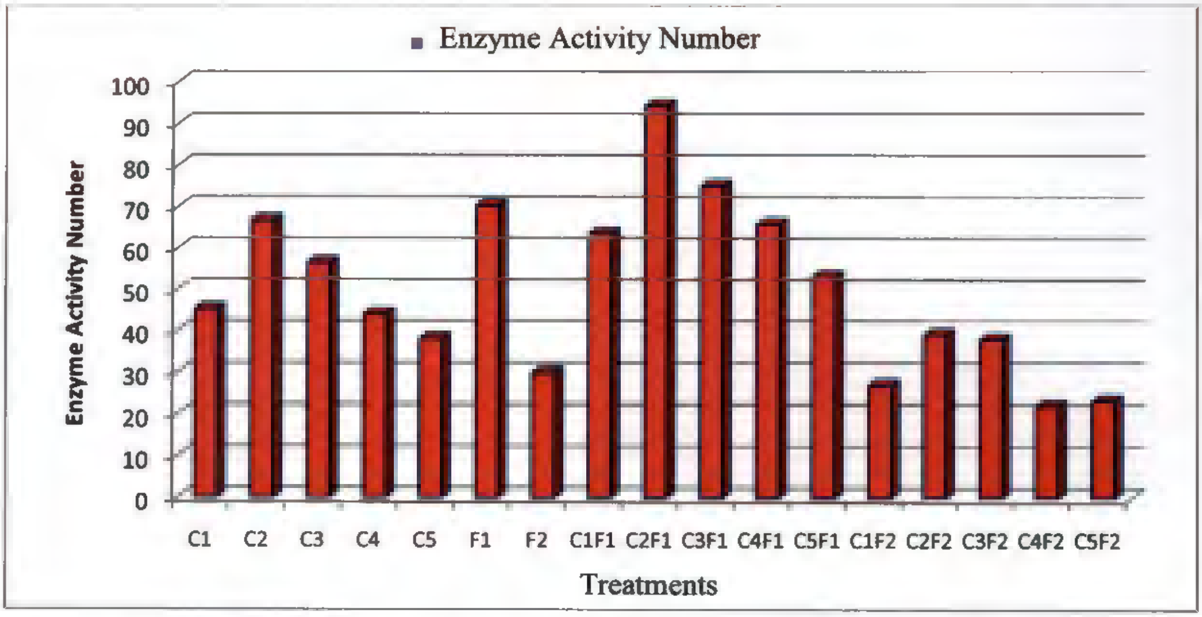

Figure 10. Enzyme activity number of the soils under coconut based cropping system-(AEU 9)

noticed in Coconut + Banana under organic system might have contributed to highest Enzyme Activity Number. Similar results have been observed by Yaroschevich (1966), organic matter addition increased the Enzyme Activity Number. It is observed that the Enzyme Activity Number gives a more realistic indication of the microbial activities. This is also evident from the result that the highest population of bacteria and actinomycetes were reported in Coconut + Banana under organic system of cultivation. The findings corroborated with the observations of Stefanic (1994).

5.9. ENZYME KINETIC PARAMETERS OF THE MAJOR ENZYMES IN THE SOILS UNDER COCONUT + BANANA CROPPING SYSTEM (ORGANIC)

Knowledge concerning the dynamics and kinetics of soil enzymes is necessary for understanding their roles in biogeochemical cycles. The rate of reaction when the enzyme is saturated with substrate is the maximum rate of reaction, V_{max}. K_m values are independent of enzyme concentration and it is really a combination individual reaction constants of the enzyme catalysed reaction. Knowledge of K_m value provides useful information regarding the interaction of enzyme with substrate. V_{max} and K_m are plotted by using the line-weaver burk double reciprocal plot (Gianfreda *et al.,* 1995).

For the cropping system with the highest enzyme activity number (Coconut + Banana under organic management), the kinetic parameters (V_{max} and K_m) were worked out. The michaelis-mentan constants (K_m) and maximum velocity (V_{max}) were determined for each enzyme *viz.,* urease, acid phosphatase and dehydrogenase.

From the study (Table 11 & 12), it was observed that urease activity is maximum at 8^{th} week, while the same was lowest at 12^{th} week. This shows that the rate of increase in initial velocity increases initially and becomes less and less with each unit of increase in substrate concentration. The increase in the activity might be due to the increased activity of microorganisms that hydrolyses urea by releasing urease (Nannipieri and Gianfreda, 1998). The lowest value of K_m for urease is noticed on 12^{th} week suggesting greater affinity of the enzyme for its substrate. The results are in accordance with the findings of Nannipierri *et al.*, 1988.

In the case of acid phosphatase, the enzyme kinetic parameter V_{max} was found to be maximum at 8^{th} week of incubation. Kinetic plots revealed that the substrate affinity was maximum at the 2^{nd} week after incubation with lowest K_m. Similar results were reported by Palmer (1995). The decrease in K_m might be due to the adsorption of enzymes to the soil surfaces.

With regard to dehydrogenase, the maximum velocity was noticed after 6^{th} week of incubation. The lowest value for K_m at 12^{th} week signifies the maximum adsorption of the enzyme. Thus it was also observed that the efficiency of dehydrogenase enzyme to decompose the substrate is directly proportional to the K_m value. These results are in confirmation of German *et al.* (2011).

5.10. MINERALIZATION OF SOIL NITROGEN

Cycles of carbon and nitrogen are strongly linked in organic cropping systems and nitrogen is frequently considered to be one of the growth limiting factor. However the synchronization between the supply nitrogen by mineralization of organic manures and crop nitrogen demand cannot be easy to achieve (Berry *et al.*, 2002). A lab incubation was carried out to study the various forms of nitrogen *viz*., total nitrogen, microbial biomass nitrogen, mineralizable nitrogen, percentage of mineralizable nitrogen to total nitrogen and microbial nitrogen quotient.

From the Figure 11, it was observed that Coconut + Vegetable under organic system of cultivation reported the highest value of total nitrogen 0.31 %. The percentage of mineralizable nitrogen to total nitrogen was found to be the highest in Coconut + Vegetable in organic system of cultivation (Figure 13). The same treatment was found to record the highest value of available nitrogen under organic system of cultivation. The highest value recorded for the microbial

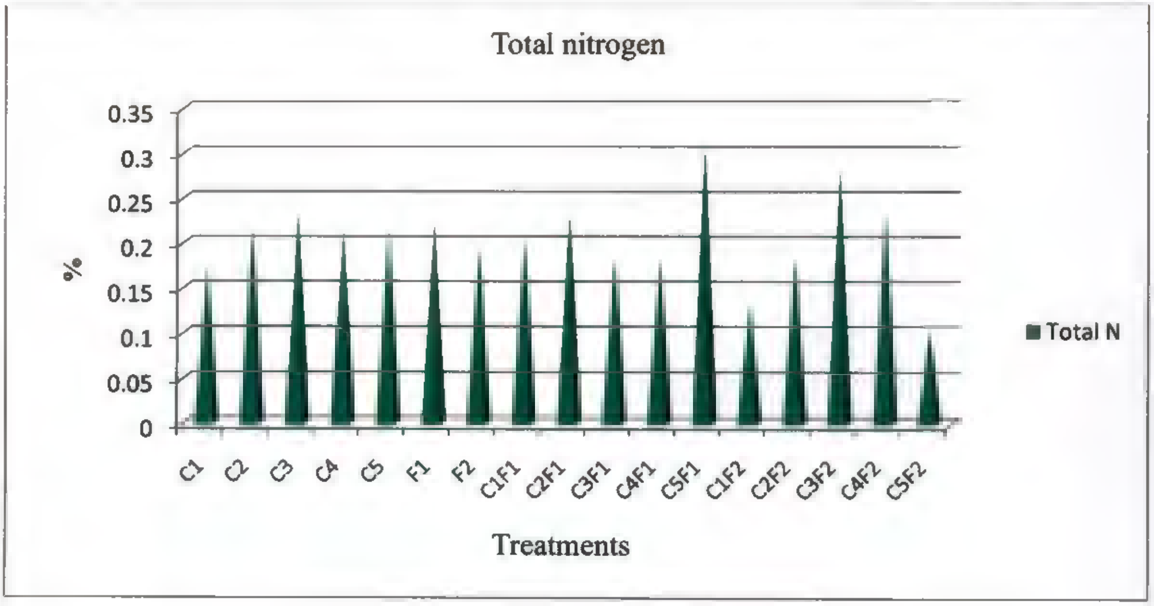

Figure 11. Total nitrogen content of the soils under coconut based cropping system-(AEU 9)

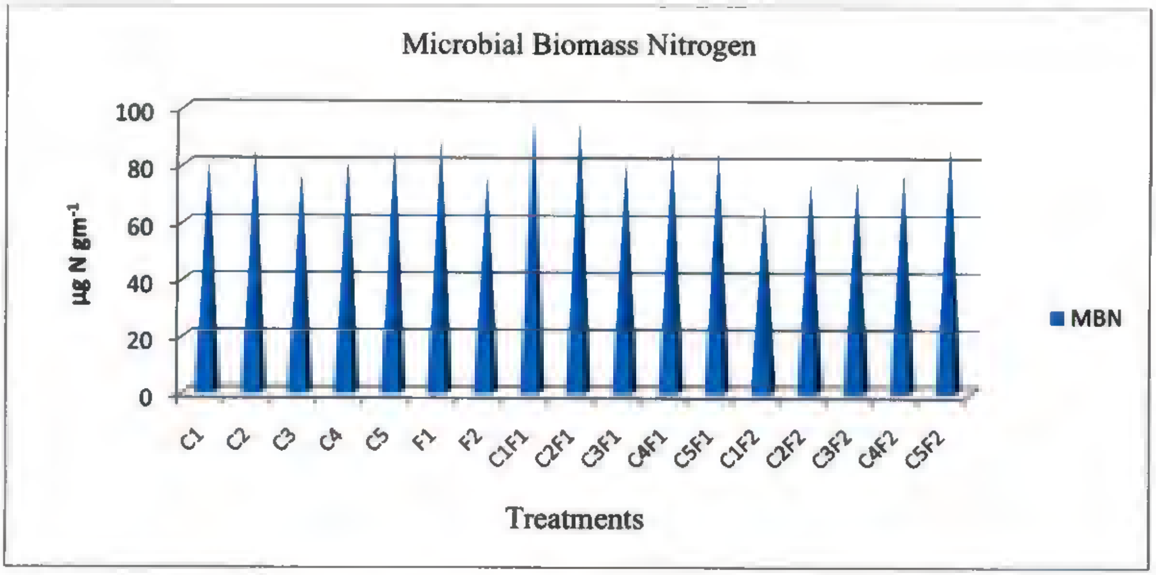

Figure 12. Microbial biomass nitrogen of the soils under coconut based cropping system-(AEU 9)

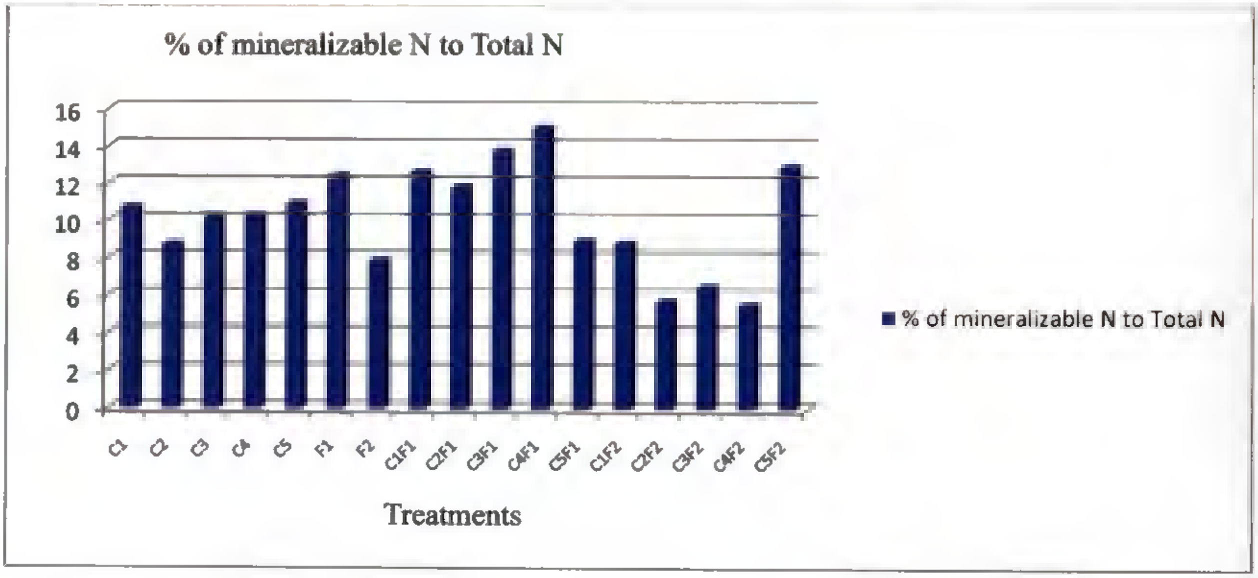

Figure 13. Percentage of mineralizable nitrogen to total nitrogen of the soils under coconut based cropping system-(AEU 9)

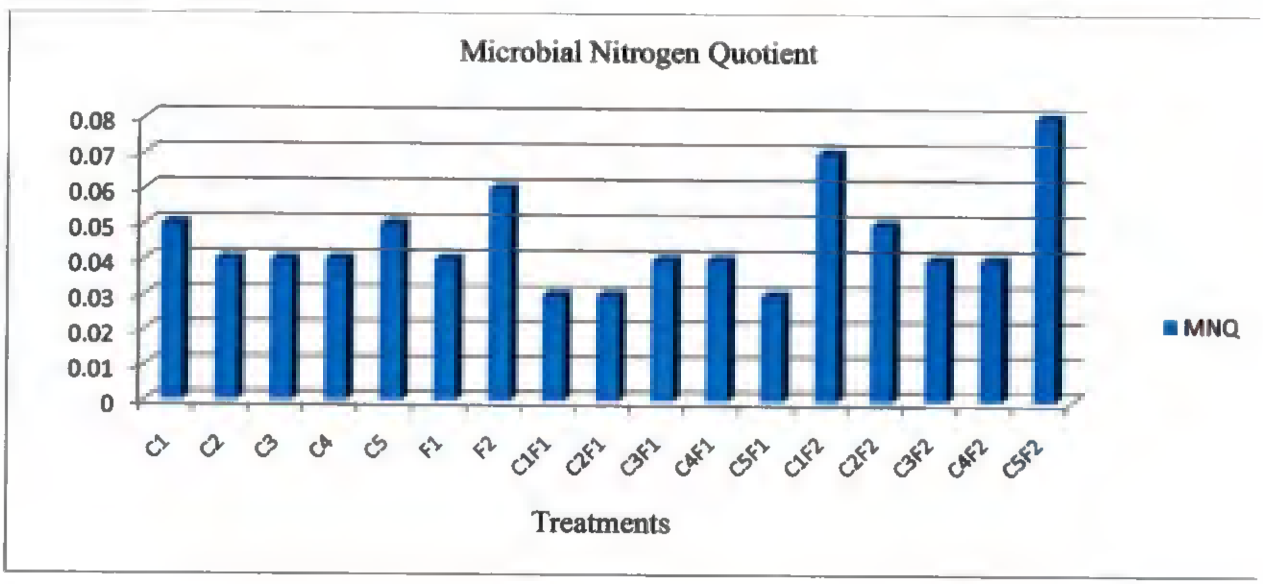

Figure 14. Microbial nitrogen quotient of the soils under coconut based cropping system-(AEU 9)

nitrogen quotient in Coconut + Vegetable under organic system (Figure 14) might have favoured the mineralization of nitrogen.

Though the microbial nitrogen quotient and percentage of mineralizable nitrogen to total nitrogen are high in Coconut + Vegetable under organic system, a relatively lesser values were recorded while enumerating the microbial population. The available nitrogen might have been used by the microbes for building cell components and thereby resulting in temporary immobilization (Amberger, 1989).

5.11. MINERALIZATION OF SOIL CARBON

Carbon mineralization is a crucial process of soil organic matter dynamics and countered with C-input, determines the amount of carbon accumulation in the soil (Cook and Allan, 2000).

A lab incubation study was carried out to assess the various carbon fractions *viz.,* organic carbon, water soluble carbon, particulate organic carbon and microbial biomass carbon.

From the study, it was observed that Coconut + Tuber under organic system of management reported to record the highest organic carbon content (Figure 15) and the highest value for water holding capacity. This might have been due to the larger quantity of biomass added under organic management system or might be due to the lesser turn over results in loss. Similar results were reported by Cook and Allan, 2000 and observed a significant and positive relationship between dissolved organic carbon and CO_2-C mineralization rates. With respect to water soluble carbon and microbial biomass carbon, Coconut + Banana under organic system was found to be the best as inferred from Figure 16 and 17. These fractions of carbon in these treatments might have supported the soil microbes by providing energy for their activities and thus resulting in increased bacterial and fungal population. Similar findings were reported by Kanojia and Kanawjia, 2004.

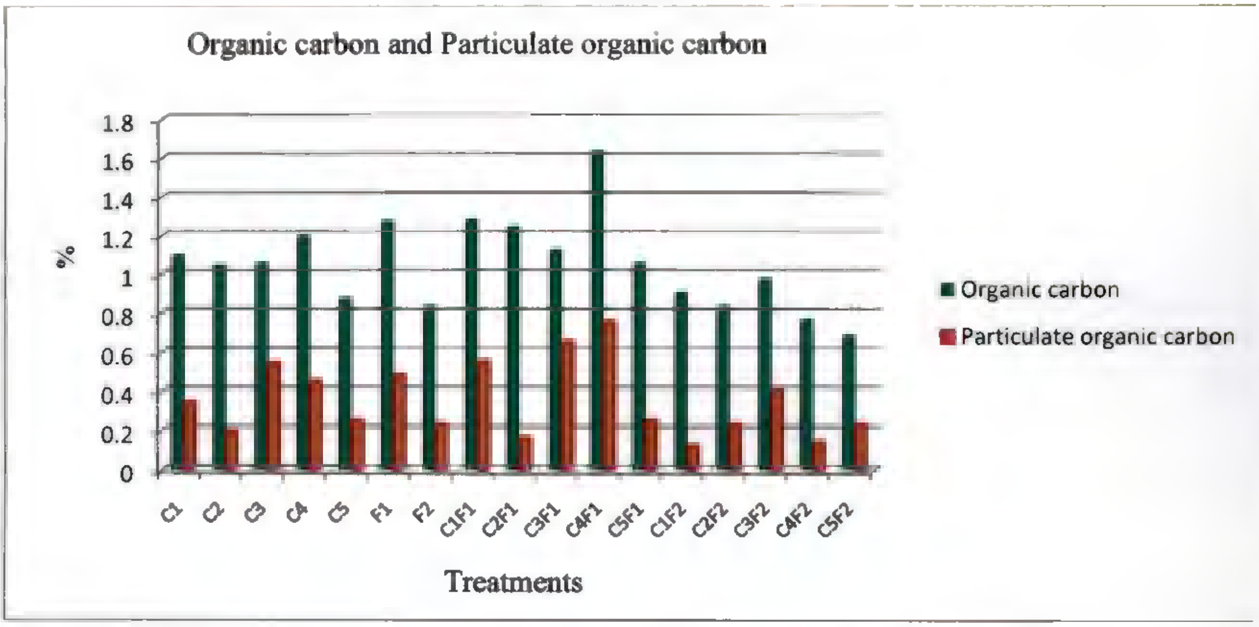

Figure 15. Organic carbon and particulate organic carbon of the soils under coconut based cropping system-(AEU 9)

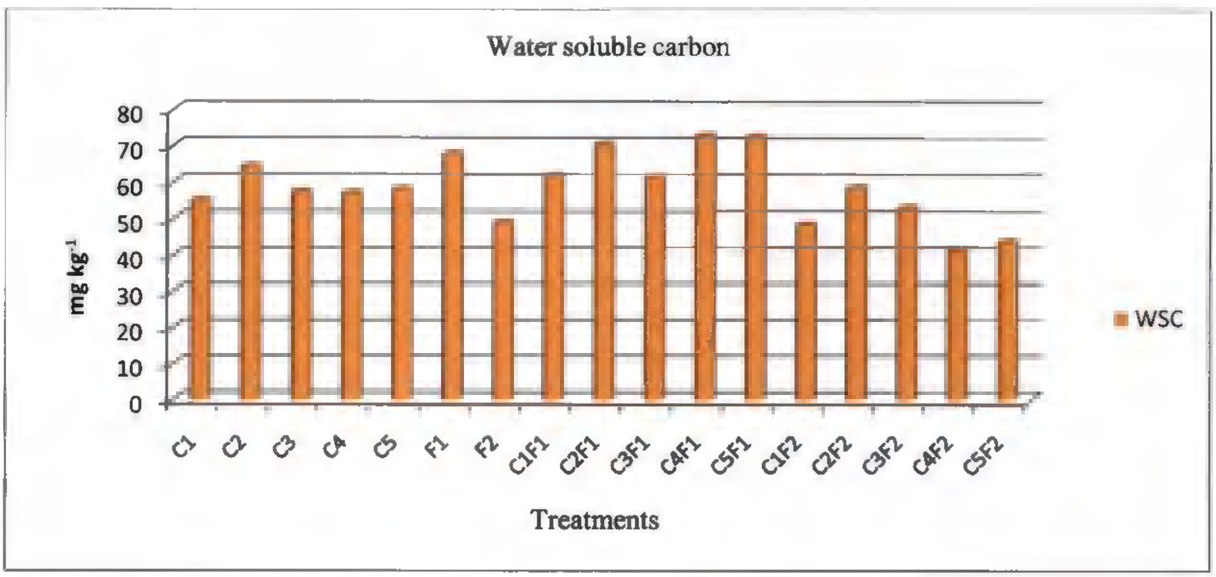

Figure 16. Water soluble carbon of the soils under coconut based cropping system-(AEU 9)

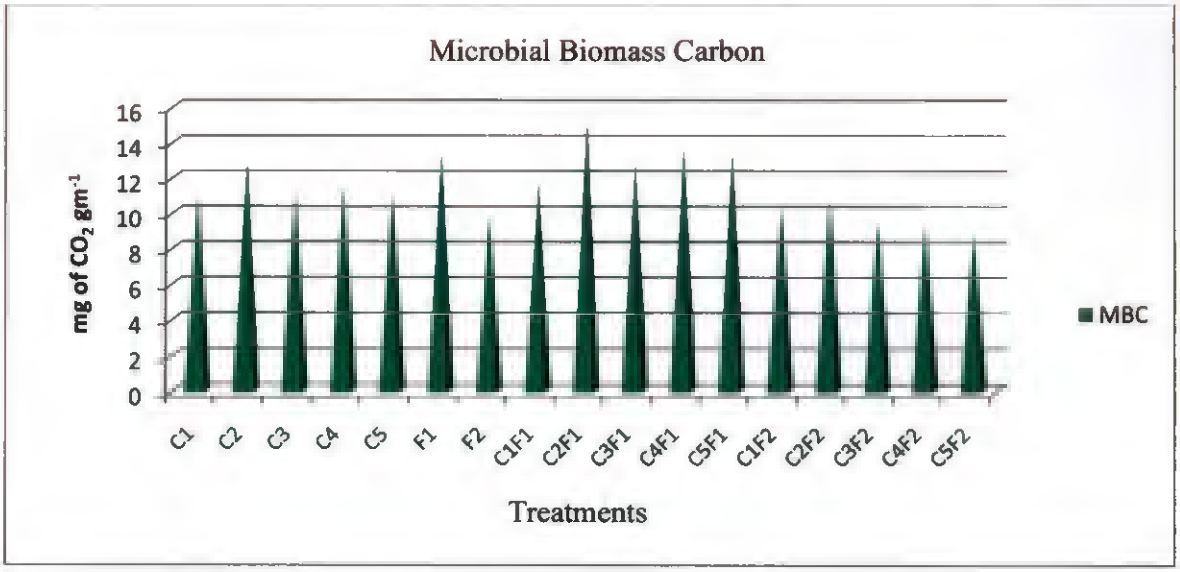

Figure 17. Microbial biomass carbon of the soils under coconut based cropping system-(AEU 9)

Another reason that can be attributed to the increased water soluble carbon in Coconut + Banana is the recycling of organic sources contributing to larger biomass that might have resulted in the findings of Paustian *et al*. (1998).

The highest water soluble carbon content of Coconut + Banana also reflects the enhanced mineralization of carbon by microbes. Thus it was concluded that the mineralization of carbon is greater in Coconut + Banana under organic system of management. This is also in agreement with the findings of Khan and Parvej (2010).

From the study conducted, the organic system of cultivation was found to increase the mineralization of carbon and nitrogen mineralization. Kinetic parameters are thus effective in discriminating between organic and conventional system. The above results are in conformity with the findings of Gaskell and Smith, 2007.

Summary

6. SUMMARY

The study entitled "Mineralization of soil nitrogen, carbon and kinetics of enzymes under coconut based cropping system" was carried out in the Department of Soil Science and Agricultural Chemistry at College of Agriculture, Vellayani, during 2015-17 to assess the mineralization potential of soil nitrogen and carbon and to evaluate the kinetic parameters of agriculturally significant soil enzymes of coconut based cropping systems in mid laterite soils of Agro Ecological Unit (AEU) 9. Soil samples were collected from five coconut based cropping systems 1. Coconut + Fodder grass, 2. Coconut + Banana, 3. Coconut + Pepper, 4. Coconut + Tuber and 5. Coconut + Vegetable under organic and conventional farming situations.

The salient findings emerged from the study are furnished in this chapter.

- Coconut + Fodder cropping system recorded the highest value for available P and actinomycetes population under organic farming and the highest values were observed for bulk density and electrical conductivity under conventional farming system.
- Coconut + Banana cropping system registered the highest values for available Fe, Zn, Mn, Cu, dehydrogenase, acid phosphatase, catalase enzymes, bacteria, fungi, microbial biomass carbon and microbial biomass nitrogen under organic system of cultivation.
- With regard to Coconut + Pepper cropping system, porosity, β-glucosidase and amylase activities and particulate organic carbon recorded the highest values under organic system of management while the highest values of available B was recorded under conventional system of management.
- Water holding capacity, available Mg, protease activity, organic carbon, water soluble carbon and particulate organic carbon recorded the highest value in Coconut + Tuber under organic system of management.

- Coconut + Vegetable cropping system recorded the highest value for pH, available calcium, total nitrogen, mineralizable nitrogen and mineralizable nitrogen to total nitrogen under organic system of cultivation while available N, available K, and microbial nitrogen quotient recorded highest value under conventional farming.

- Highest value for Enzyme Activity Number was registered in Coconut + Banana cropping system under organic management situation followed by Coconut + Pepper. Based on the assessment of soil quality using biological indicators , Coconut + Banana under organic system of management was found to be the best system .

- Biological parameters of soils registered the highest values for Coconut + Banana cropping system for enzyme activities (dehydrogenase, acid phosphatase and catalase) and microbial activity (bacteria and fungi).

- Coconut + Tuber cropping system favours the mineralization of carbon with higher values of organic carbon, water soluble carbon and particulate organic carbon under organic situation.

- Coconut + Vegetable cropping system favour the mineralization of soil nitrogen with the highest values for microbial total nitrogen, mineralizable nitrogen, percentage of mineralizable nitrogen to total nitrogen under organic system of cultivation.

- The study also revealed that the V_{max} for urease and acid phosphatase exhibited the highest value after 8^{th} week of incubation, while the dehydrogenase recorded the highest V_{max} after 6^{th} week of incubation. Considering the constant K_m, the enzymes urease and acid phosphatase exhibited the highest value after 8^{th} week of incubation, while the dehydrogenase recorded the highest V_{max} after 6^{th} week of incubation.

- Correlation studies between micronutrients with enzyme activities showed a significant and positive correlation between dehydrogenase, catalase and amylase with Fe, Zn, Mn and Cu. Acid phosphatase exibited a positive correlation with Fe, Zn, Mn, Cu and B. While a positive correlation existed between Zn and B and protease.

- Correlation study between microbial load and enzyme activities showed a significant and positive correlation between dehydrogenase, catalase and amylase with bacteria, fungi and actinomycetes. Acid phosphatase exibited a positive correlation with fungi and actinomycetes. β-glucosidase exibited a positive correlation with bacteria.

6.1 CONCLUSION

- From the study, it is concluded that, under the various cropping systems and farming systems Coconut + Banana (organic) recorded the highest enzyme activity and thus making it biologically sustainable.
- Coconut + Tuber cropping system and Coconut + Vegetable cropping system under organic management system favoured the mineralization of carbon and nitrogen respectively.

6.2 FUTURE LINE OF WORK

- To detail the relationship between micronutrients and enzymes.
- Generating maps using Geographical Information System (GIS) tools based on the biological status of the soil.

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Appendices

APPENDIX I

DETAILS OF TREATMENT COMBINATIONS

Treatments	Details
Organic Farming	
C_1F_1	Coconut + Fodder grass
C_2F_1	Coconut + Banana
C_3F_1	Coconut + Pepper
C_4F_1	Coconut + Tuber
C_5F_1	Coconut + Vegetable
Conventional Farming	
C_1F_2	Coconut + Fodder grass
C_2F_2	Coconut + Banana
C_3F_2	Coconut + Pepper
C_4F_2	Coconut + Tuber
C_5F_2	Coconut + Vegetable

APPENDIX II

COMPOSITION OF MEDIA FOR MICROBIAL ENUMERATION

1. Enumeration of Bacteria

Media: Nutrient Agar

Composition

1. Peptone - 5 gm
2. NaCl - 5 gm
3. Beef extract - 3 gm
4. Agar - 20 gm
5. pH - 7.0
6. Distilled water - 1000 ml

2. Enumeration of Fungi

Media: Rose Bengal Agar

Composition

1. Glucose - 3g
2. $MgSO_4$ - 0.2 g
3. K_2HPO_4 - 0.9 g
4. Rose Bengal - 0.5 g
5. Streptomycin - 0.25 g
6. Agar - 20 g
7. Distilled water - 1000 ml

3. Enumeration of Actinomycetes

Media: Kenknight's Agar

Composition

1. Dextrose - 1 g
2. KH_2PO_4 - 0.1 g
3. $NaNO_3$ - 0.1 g
4. KCl - 0.1 g
5. $MgSO_4$ - 0.1 g
6. Agar - 15 g
7. Distilled water - 1000 ml

MINERALIZATION OF SOIL NITROGEN, CARBON AND KINETICS OF ENZYMES UNDER COCONUT BASED CROPPING SYSTEM

by

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ABSTRACT

A study entitled "Mineralization of soil nitrogen, carbon and kinetics of enzymes under coconut based cropping system" was carried out during 2015-17 in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani. The study was envisaged toassess the mineralization potential of soil nitrogen and carbon and to evaluate the kinetic parameters of agriculturally significant soil enzymes of coconut based cropping systems in mid laterite soils of Agro Ecological Unit (AEU) 9. Soil samples were collected from five coconut based cropping systems 1. Coconut + Fodder grass 2. Coconut + Banana, 3.Coconut + Pepper, 4. Coconut + Tuber and 5. Coconut + Vegetable under organic and conventional farming situations.

With regard to physical properties, the lowest bulk density of 1.30 Mg m^{-3} was noticed in Coconut + Vegetable under organic management. Coconut + Tuber under organic system recorded the highest value for water holding capacity (19.86 %). The highest porosity was noticed under Coconut + Pepper (41.60 %) cropping system, while the interaction effects of cropping and farming systems on porosity was non significant. With regard to the electrochemical properties, the highest pH of 5.33 was noticed in Coconut + Vegetable under organic management and the lowest EC value of 0.26 dSm^{-1} was noticed in Coconut + Pepper and Coconut + Tuber under conventional management system.

Analysis of available nutrient status revealed that the N and K status were higher in Coconut + Vegetable cropping system under conventional management *viz.*, 326.14 kg ha^{-1} and 183.68 kg ha^{-1}, while the highest value of available P (91.87 kg ha^{-1}) was noticed in Coconut + Fodder under organic management. Among the secondary nutrients, calcium was noticed highest in Coconut + Vegetable (310.59 mg kg^{-1}) and magnesium in Coconut + Tuber (143.49 mg kg^{-1}) under organic management. Coconut + Banana under organic management system recorded the

highest available micronutrient status of Fe, Zn, Mn and Cu *viz.*, 45.19 mg kg^{-1}, 1.64 mg kg^{-1}, 23.29 mg kg^{-1} and 5.74 mg kg^{-1} respectively, while Coconut + Pepper recorded the highest boron content (1.5 mg kg^{-1}) in the conventional management system.

Coconut + Banana cropping system under organic management situation recorded the highest activities of major enzymes *viz.*, dehydrogenase, acid phosphatase and catalase *i.e.*, 462.52 μg of TPF released g^{-1} of soil 24 h^{-1}, 80.35 μg of p-nitrophenol released g^{-1} of soil 24 h^{-1} and 3.90 % of H_2O_2 hydrolysed g^{-1} of soil h^{-1} respectively. In general, the enzyme activities were found to be the highest in organic farming situation than the conventional farming situation. In the case of β-glucosidase and amylase, Coconut + Pepper recorded the highest values *viz.*, 4.10 μgpnp D-glucosidase g^{-1} soil h^{-1} X 10^{-4} and 13.82 μM of maltose g^{-1} of soil respectively.The highest values of bacterial count of 8.04 log cfu g^{-1} and actinomycetes count of 4.30 log cfu g^{-1} were noticed in Coconut + Banana under organic system of management.

Enzyme activity number (EAN) was calculated using the expression EAN = 0.2{TPF+catalase (%)/10 + phenol (μg)/40 + amino-N (μg)/40 + amylase (%)/20}.The highest value for EAN was noticed in Coconut + Banana under organic system (94.01) followed by Coconut + Pepper (74.92). With respect to mineralization of soil carbon, the highest values for organic carbon, water soluble carbon and particulate organic carbon 1.63%, 72.74 mg $kg^{-1}$and 0.75 % respectively were noticed for Coconut + Tuber under organic management. The highest microbial biomass carbon noticed in Coconut + Banana (15.11 mg of CO_2 g^{-1}) might have contributed to the higher enzyme activity and thus higher enzyme activity number (EAN). In the case of mineralization of soil nitrogen, Coconut + Vegetable (organic) recorded the highest value of 281.80 mg kg^{-1} for mineralizable nitrogen and 0.31% for total nitrogen thus contributing to14.95 % of mineralizable nitrogen to total nitrogen. From the enzyme kinetics studies, V_{max} was found to be maximum in the 8^{th} week for urease and acid phosphatase and 6^{th} week for dehydrogenase.

From the study, it is concluded that Coconut + Tuber and Coconut + Vegetable cropping system under organic farming situation favours the mineralization of carbon and nitrogen respectively. Coconut + Banana under organic situation was found to be the best with respect to the soil biological properties.