Biological Profile of Ferralitic Alluvial Paddy Soils Under Long Term Differential Fertilizer Application

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Biological Profile of Ferralitic Alluvial Paddy Soils Under Long Term Differential Fertilizer Application"** 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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CERTIFICATE

Certified that this thesis entitled **"Biological Profile of Ferralitic Alluvial Paddy Soils Under Long Term Differential Fertilizer Application"** is a record of research work done independently by Mr. Nikhil K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

%	Per cent
@	At the rate of
µg	Microgram
^{0}C	Degrees Celsius
AICRP	All India Co-ordinated Research Project
C	Carbon
CD	Critical difference
cfu	Colony forming units
cm	Centimetre
DAI	Days after incubation
et al.	And others
Fig.	Figure
ft	Feet
FYM	Farmyard Manure
g	Gram
hr.	Hour
ha^{-1}	Per hectare
HWC	Hot water extractable carbohydrates
i.e.	That is
K	Potassium
KAU	Kerala Agricultural University

kg	Kilogram
LTFE	Long Term Fertilizer Experiment
m	Metre
MBC	Microbial biomass carbon
mg	Milligram
ml	Millilitre
N	Nitrogen
nm	Nanometre
ORARS	Onattukara Regional Agriulture Research Staion
(PMT-Dwarf)	Permanent Manurial Trial with Dwarf indica rice variety
(PMT-Tall)	Permanent Manurial Trial with Tall indica rice variety
P	Phosphorous
plant^{-1}	Per plant
PMT	Permanent manurial trial
POP	Package of Practices
ppm	Parts per million
PSB	Phosphorous Solubilizing Bacteria
RARS	Regional Agricultural Research Station
s	Seconds
t	Tonnes
TPF	Triphenyl Formazan
TTC	Triphenyl tetrazolium chloride
VAM	Vesicular arbuscular micorrizhae
Viz.	Namely

Introduction

1. INTRODUCTION

The importance of long term fertilizer experiments in studying the effects of continuous cropping and fertilizer or manure application on sustenance of crop production is widely recognized (Manna *et al.,* 2007). Such experiments provide an opportunity to evaluate the sustainability of agricultural practices (Jenkinson, 1991). Many intensive cereal based cropping systems are under practice in the country specific to agro-climatic regimes. As rice-rice cropping system is the predominant crop sequence in the lateritic belts of Kerala state, close monitoring of the yield, nutrient uptake and nutrient dynamics and changes in physical, chemical and biological properties of soil occurring due to continuous use of fertilizers or manures assume great significance for the sustainability of this cropping system. Long term application of NPK fertilizers alone without the use of organic amendments has resulted in secondary and micronutrient deficiencies which seriously impair the response to applied fertilizer and reduce the yield potential considerably.

Permanent plot experiments become more useful when periodical soil analysis and critical analysis of soil test data are made. Long term fertilizer experiments involving varying combinations of organic and inorganic plant nutrients provide valuable information for planning strategies and polices for ensuring sustainable crop production without risking soil health. The data emanating from such experiments explain the nutrient behaviour in soils over the years under seasonal influences and their residual accumulation in soils leading to build up of soil fertility.

The Permanent Manurial Trials and the All India Co-ordinated Project on long term fertilizer experiment have been laid out at Regional Agricultural Research Station, Pattambi with the main objectives of studying the effect of continuous application of plant nutrients (NPK) in organic and inorganic forms and in combinations on sustainable production in the rice-rice cropping sequence being practiced there. The first Permanent Manurial Trial with tall indica rice variety was started in Kharif, 1962 and the second Permanent Manurial Trial with

dwarf indica rice variety, in Kharif, 1972. The AICRP on long term fertility experiment was initiated in Kharif 1997. The three field experiments are being conducted continuously in the same fields, the present Kharif crops of these experiments being in their 101st, 81st and 31st season respectively. Season wise monitoring of the changes in soil physical and chemical properties is being done regularly in addition to yield analysis.

Soil biological properties which respond rapidly to any change in soil quality have been suggested as better indicators of soil health than physical and chemical properties which alter only after a drastic change in soil quality. The relationship between various crop management practices and soil biological functions is well recognised and accepted through not well understood. Monitoring changes in various biological properties offers a promise for better understanding of nutrient availability and hence have been used on a limited scale as sensors in studies on soil fertility as influenced by management practices (Bending *et al*., 2004).

However in spite of the recognition and establishment of the relationship between the biological properties of soils and their effect on soil quality/ health, very little attention has been given to his critical aspect as is the case everywhere. Little information is available on changes in biological properties due to long term application of organic manures or inorganic fertilizers in rice based cropping system even on a national scale. In the long term fertility trials at RARS, Pattambi also, no study has so far been done on the biological properties of these soils at any stage of the experiments except enumeration of a few soil microorganisms at the beginning of LTFE. Soil biological properties are contributed by the biological components of the soil which constitute upto 10 per cent of soil organic matter. Being the most sensitive, these properties fluctuate rapidly in response to agricultural practices especially nutrient application. The quantity, form and proportion of the various nutrients added have profound influence on the interactions among the soil biological community and diversity. As soil health is an interaction of the measurable physical, chemical and

biological properties of a particular soil, any management strategy planned for sustaining soil health and crop production will not fetch result if the biological properties of the soil are not given the same weightage as the physico- chemical properties, if not more, especially under long term fertilizer application.

The present study is proposed with the objective of understanding the important biological properties of soils of RARS, Pattambi under long term fertilizer application as a result of continuous nutrient addition in organic, inorganic and combination forms. The relationship between these properties and yield and yield bearing soil and crop components of the rice-rice cropping sequence will also be studied. Though a comparison in terms of changes that the biological properties have undergone over the years due to continuous nutrient application cannot be made due to lack of basic data on these parameters the findings and interpretations evolving from this study will help in planning better and judicious biological management strategies for these soils for sustainable health and crop production.

Review of Literature

2. REVIEW OF LITERATURE

Long term fertilizer experiments involving varying combinations of organic and inorganic plant nutrients provide valuable information for planning strategies and policies for ensuring sustainable crop production without risking soil health. The data emanating from such experiments explain the nutrient behaviour in soils over years under seasonal influences and their residual accumulation in soils leading to build up of soil fertility.

But in spite of the recognition and establishment of the relationship between the biological properties of soils and their quality/ health lesser attention has been given to this critical aspect of the soils by research workers undertaking studies on the long term effect of nutrients on soils. Hence literature pertaining to the study is limited especially with reference to rice-rice cropping sequence. In this chapter a detailed review on the long term effect of nutrient application on the biological properties of some soils under different land use pattern is given.

2.1 BIOLOGICAL PARAMETERS

2.1.1 Soil Macrofauna

2.1.1.1 Earthworms

Scullion and Ramshaw (1987) studied the effect of various manurial treatments on earthworm activity in grasslands and reported that poultry manure application increased population of earthworms.

Reganold and Palmer (1995) used earthworm population, total earthworm weight and average worm weight as biological indicators of soil health. Ten earthworms ft^{-2} of soil surface can be considered as a good population in agricultural system.

In a long term maize-wheat-cowpea experiment started in 1971 in India, Kanchikerimath and Singh (2001) found that earthworm activity was generally increased when FYM was added to soil and that the earthworm biomass decreased with application of chemical fertilizers without organic inputs. The trend became greater with increasing time.

Cao *et al*. (2004) studied the effect of various combinations of chemical fertilizers, crop residues and organic fertilizers on earthworm populations in a high production agro-ecosystem in North China. The earthworm density of the treatments had the following ascending trend: chemical fertilizer < chemical fertilizer + wheat straw < chemical fertilizer + wheat straw + corn stover < chemical fertilizer + wheat straw + corn stover + organic fertilizer.

Zaller and Kopke (2004) found that plots with the application of FYM (30 t ha^{-1} $year^{-1}$) had significantly increased earthworm cast production and altered earthworm community composition, soil pH, P and K concentrations, microbial biomass and dehydrogenase activity than plots without FYM application.

In the Bad Lauchstadt long-term experiment in Germany, Marhan and Scheu (2005) found that FYM and NPK+FYM increased earthworm biomass by 19.7 and 42.8 per cent respectively, while the NPK treatment decreased earthworm biomass by 9.4 per cent. They concluded that the application of NPK fertilizers alone could not sustain the earthworms, but NPK+FYM could do so by increasing the utilizable soil organic matter pool.

2.1.1.2 Arthropods

Ginsberg (1993) and New (1995) suggested arthropod species as potentially valuable tools for monitoring changes in soil health.

Soil micro arthropods play important role in mineralization process either directly through their participation in decomposition or indirectly by regulation of soil microbial biomass. The ability of micro arthropods population on litter decomposition and nutrient release have been well documented by Robert (1995), Tian *et al.* (1998) and Adejuyigbe *et al.* (1999)

Scholte and Lootsma (1998) studied the effect of FYM and green manure crops on populations of mycophagous soil fauna and observed that FYM had a stimulative effect on micro arthropods. Axelsen and Kristensen (2000) from studies on collembola and mites in plots fertilized with different types of green

manure reported that the input of organic matter in various forms, such as green manures and crop residues, increased populations of micro arthropods.

Miyazawa *et al*. (2002) based on investigations on the effect of cropping system and fallow management on micro arthropod populations concluded that application of organic matter increased the number of micro arthropods by supplying various nutrients, enhancing plant growth and altering soil conditions.

Kang *et al*. (2005) observed that organic farming practices have a positive effect on soil microbial numbers, processes and activities. Collembola decreased with increase in the level of spent oil under all sources of organic amelioration. Total micro arthropod population was also observed to decrease with increase in the level of spent oil for all treatments except soils in the control and those ameliorated with cow dung.

Sjursen *et al.* (2005) studied the effect of long term fertilization on micro arthropod abundance in three sub-arctic ecosystems and reported that inorganic fertilization increased population of micro arthropods.

Eo and Nakamoto (2007) reported higher population densities of micro arthropods in the organically fertilized plots, which they attributed to higher microbial activities.

From investigations on the response of micro arthropods to organic fertilization in the Federal University of Agriculture, Abeokuta farm, Olla *et al.* (2013) reported that soil micro arthropod population decreased with increase in the level of spent oil while addition of poultry manure significantly improved their population particularly that of collembola by about 48.48 percent over that of the control plots. The result indicated the positive impact of organic manures on both soil chemical properties and micro arthropod population density.

2.1.2 Soil Microflora

According to Rao *et al.* (1995), to maintain productivity and ecological sustainability of soil, biofertilizers are essential which are products containing

living cells of microorganisms which can mobilise plant nutrient elements from non-usable to usable form through biological processes.

2.1.2.1 Bacteria

From results of ten year long studies on soil microbial and biochemical properties with urea and anhydrous ammonia Biederbeck *et al.* (1996) reported that bacterial and fungal populations were positively related to applied N rate and were greater in soil treated with anhydrous ammonia than in urea- treated soil.

Bhattacharya *et al*. (1996) opined that regulated addition of organic matter as a practice profoundly influences the different groups of microorganisms in the rice rhizosphere

Tiwari *et al.* (2000) found that the total bacterial count showed superiority over Azotobacter, fungi and actinomycetes with the incorporation of wheat straw and biogas slurry at different levels of N up to the flowering stage of a crop and decreased at harvest.

Jain *et al.* (2003) who studied the effect of different nutrient sources on biological properties of a vertisol reported no negative impact of chemical fertilizers on bacterial population.

According to Selvi *et al.* (2004) application of FYM @ 10 t ha^{-1} to finger millet annually along with 100 per cent NPK recorded the highest bacterial counts at the end of rotation followed by 150 per cent NPK.

Biederbeck *et al*. (2005) found that inclusion of green manure in a continuous wheat cropping system resulted in an increase of 385 per cent in number of bacteria, 210 per cent in fungi, 178 percent in microbial biomass carbon, 202 percent in soil dehydrogenase activity and 171 per cent in phosphatase activity.

Addition of rice straw, rock phosphate and pyrite brought about a significant increase in the population of non-symbiotic nitrogen fixing and ammonifying bacteria (Debnath *et al*., 2005).

Based on the results of a long term fertilizer experiment in Cuu Long Delta Rice Research Institute, in South Vietnam Tuyen *et al*. (2008) reported that bacterial population was the highest among all other microorganisms. It ranged from 156 $x10^6$ to 3760 $x10^6$ cfu g^{-1} air dry soil.

2.1.2.2 Actinomycetes

Results of long term fertilizer experiments from some centers like Coimbatore, Ranchi and Palampur indicate that continuous application of FYM with NPK resulted in greater counts of soil actinomycetes (Swarup, 2000).

Selvi *et al*. (2004) in a study on microbial population and biomass in rhizosphere as influenced by continuous intensive cultivation and fertilization in an Inceptisol found an increase in population of actinomycetes through the application of 100 per cent NPK + FYM as compared to FYM minus treatments.

Tuyen *et al*. (2008) from a long term fertilizer experiment in Cuu Long Delta Rice Research Institute reported that actinomycetes population was relatively high among microorganisms and it ranged from 52 $x10^6$ to 487 x 10^6 cfu g^{-1} air dry soil.

Bhadhur *et al*. (2012) who studied the effect of integrated nutrient management on yield, microbial population and changes in soil properties under rice-wheat cropping system reported that different treatments of nutrient management caused increase in the actinomycetes population ranging from 10 x 10^5 to 19 x 10^5 cfu g^{-1} soil.

2.1.2.3 Fungi

Domsch *et al*. (1980) and Subramanian (1983) were able to isolate the fungal genera active in decaying organic debris.

Population of fungi reduced by more than one half by NPK + lime treatment in an All India coordinated long term fertilizer trial conducted on a red loam soil at Ranchi, while the same treatment presented a favourable impact on

nodular bacteria in soybean increasing the number of nodules and also their weight plant^{-1} (Nambiar, 1994).

Jordan *et al.* (1995) suggested certain microbial parameters such as soil fungal biomass, microbial biomass carbon and nitrogen potential as indicators of soil quality in the surface soils under short and long term cropping systems in Central Missouri.

Baath *et al*. (1995) observed a change in humus layer microbial community structure two years after wood ash fertilization.

Mukherjee and Rai (1999) opined that the VAM fungi *Glomus fasciculatum, Glomus macrocarpum and Pseudomonas striata* had a positive influence on P-nutrition and uptake and also root biomass.

Greater microbial populations in FYM treated plots as compared to chemically amended plots were reported by Venkateswarlu (2000).

Hackl *et al.* (2000) indicated that the plant species growing on a soil has a profound influence on the population and species composition of the soil fungi inhabiting that soil.

Gopalaswamy and Kannaiyan (2002) found that the fungal population was the highest in the FYM and vermicompost applied treatments.

From a study on fungal population and diversity in organically amended agricultural soils of Meghalaya, Swer *et al.* (2007) reported that fungal population was comparatively higher in organically amended plots as compared to control. Among all the treatments FYM showed significantly higher fungal population.

Tuyen *et al*. (2008) on the basis of the results of a long term fertilizer experiment in Cuu Long Delta Rice Research Institute reported that fungus population was the lowest, and it ranged from 0 to 0.725 x10^6 cfu g^{-1} air dry soil.

Nnafi and Oghu (2011) assessed the effects of long term organic and inorganic manuring on soil health and productivity of the Niger delta soils and

reported that the highest bacterial and fungal populations were observed after 21 to 52 weeks of fertilizer application.

2.1.2.4 Azospirillum

Gopalaswamy and Kannaiyan (2002) reported that incorporation of organic manure as *Azolla* stimulated the populations of nitrogen fixing *Azospirullum* and *Azotobacter* as well as those of other beneficial organisms and their activities significantly over that by prilled urea in wet land soils.

The beneficial effect of *Azospirillum* application to crops can be attributed to its nitrogen fixation capacity and stimulating effect on root development (Wua *et al.,* 2004; Noshin *et al.*, 2008).

El- Komy (2004) observed that application of *Azospirillum* to crops can exert a positive effect on plant growth which may be the resultant of multiple effects including synthesis of phyto- hormones, N_2- fixation, nitrate reductase activity and enhancement of minerals uptake.

Sharma *et al*. (2009) noticed increased microbial population and their activity in a North West Himalayan acid soil under rice - wheat cropping due to long term addition of Lantana residue.

Lavanya *et al*. (2012) studied the influence of phosphobacterium and other biofertilizers with different sources of P on lowland rice crop in the North-Eastern zones of Tamil Nadu and recognized that addition of biofertilizers like Azospirillum and phosphobacterium at two kg ha^{-1} had certainly an effect in increasing the grain yield and other biometric parameters.

2.1.2.5 Azotobacter

From studies on the effect of different organic waste material on soil biological properties, Cengel and Okur (2000) reported that in comparison to control, the application of fishmeal increased in general *Azotobacter* by 246 per cent.

Jain *et al*. (2003) reported that FYM + 100 per cent NPK increased the population of *Azotobacter* in comparison to treatments not having FYM in laterite soil.

Activities of dehydrogenase and phosphatases in a Vertisol soils were significantly improved upon inoculation with *Azotobacter* (Aseri and Rao, 2005).

Bhadhur *et al*. (2012) based on a study on the effect of integrated nutrient management on yield, microbial population and changes in soil properties under rice-wheat cropping system reported that population of symbiotic diazotrophic *Azotobacter* varied significantly among treatments from 18 x 10^2 to 48 x 10^2 cfu g^{-1} soil.

2.1.2.6 P Solubilizers.

Addition of organic matter improves the physical and biological properties of soil including phosphate solubilisation (Bisoyi and Singh, 1988).

Raju and Reddy (1999) concluded that application of 100 percent recommended P to rice as single super phosphate + phosphate solubilising bacteria and 2/3 single super phosphate + 1/3 rock phosphate along with phosphate solubilising bacteria application were the best integrated phosphorus management strategies for wet seeded rice for increasing the phosphorus uptake, grain yield and phosphorus use efficiency.

Lal *et al.* (2000) reported that the highest number of and phosphate solubilising microorganisms was harboured by *Subabul* treated soils. They also reported that in the case of rice straw, lantana tops and *Ipomoea* tops treated soils, the population of phosphate solubilizers increased up to 60 days.

Gayathry (2002) reported that the increase in root length in rice crop may be due to phosphate availability in soil by phosphate solubilizing bacteria that are distributed in wide area of soil.

Results of long term experiments using different nutrient sources in a Vertisol over 25 years indicated no negative impact for the chemical fertilizers on

the population of nitrifying and phosphate solubilizing bacteria (Jain *et al*., 2003). More population was observed following fertilizer application compared to control.

Hshuan (2006) reported that phosphorous solubilising bacteria culture increased rice yield up to 200-500 kg ha^{-1} thus saving nearly 50 per cent of dose of P.

Application of Suaeda compost in combination with FYM and phosphate solubilizing bacteria significantly increased the soil microflora such as bacteria, fungi and actinomycetes and soil enzyme activities such as dehydrogenase, alkaline phosphatase, cellulase and urease in soil cultivated with *Arachis hypogaea* as observed by (Balakrishnan *et al*., 2007).

Jamuna *et al*. (2012) in a study on effect of phosphate solubilizing bacteria on rice crop reported that higher shoot length, total panicle to productive panicle ratio and straw yield were recorded in case of poly urethane foam immobilised cyanobacterial cultures with rock phosphate.

2.1.3 Soil Enzymes

Soil enzyme activities which have been suggested as suitable indicators of soil quality mainly originate from microorganisms, (Ladd, 1978) animals and plants (Tabatabai, 1994) as well as from the decomposition of plants and animal residues (Shan *et al.,* 2008). Soil enzymes play an important role in the mineralisation process and also in many other soil biological reactions which are truly microbial in origin (Tate, 2000).

2.1.3.1 Urease

Urease, the enzyme that catalyses the hydrolysis of urea to CO_2 and NH_3 is widely distributed in nature and has been detected in plants, animals and microorganisms. Variation in urease activity within and between soil groups have been related to soil properties, types of vegetation and cultural practices.

Bremner and Mulvaney (1978) reported that urease is unique among soil enzymes extracted in that the enzyme-humus conjugate represents 20- 40 per cent of total enzyme activity in soil.

Dick *et al*. (1988) found that long term addition of inorganic nitrogen fertilizer decreased enzyme activities like urease and amidase while manure and crop residues increased them. Activity of urease increases with increase in moisture content of soil as reported by Kandeler and Gerber (1988).

Rao and Burns (1990) through their studies on the effects of biofertilizers on urease activity found that blue green algae improved the urease enzyme activity through increasing the soil aggregation.

After studying the urease immobilized on surface modified clays Tabatabai (1992) reported that there is an optimum pH for enzyme activity which does not shift upon enzyme immobilization. Fenn *et al*. (1992) found that urease activity decreases with increase in profile depth and the greatest decrease could be noticed below the plough depth.

Torello and Wehner (1993) found that higher amounts of NH_3 liberation from moist turf manured with urea resulted in lesser activity of urease.

Singaram and Kamalakumari (1995) in a long term field experiment in a Typic Ustropept observed enhanced activities of soil enzymes with higher rates of N, P and K fertilization with or without FYM. Rao and Pathak (1996) reported based on their study on ameliorative influence of organic matter on the biological properties of salt affected soil concluded that application of coir pith compost recorded the highest urease activity in soil followed by pressmud application.

Park and Seaton (1996) reported that the activity of urease was greater in the surface than in the lower Ap horizon, rich in organic carbon. Studies on urease activity by Dinesh *et al*. (1998) also confirmed urease activity in forest soils and reported that activity ranged from 245.60 to 290.80 ppm of urea hydrolysed g^{-1} soil 24 hr^{-1}.

A long-term intensive monoculture usually supplies lower amounts and diversity of organic matter than crop rotation, thus suppressing microbial activities and consequently decreasing enzyme activities (Klose and Tabatabai, 2000).

Greater enzyme activities in the green manure amended soil was the result of not only a large microbial mass, but also higher amount of endoenzymes, greater enzyme production by microbial biomass and direct contribution of enzymes by green manure. (Dinesh *et al.,* 2000) and higher degree of stabilization of enzymes in humic substances and increased soil organic carbon concentration (Elfstrand *et al.,* 2007).

Integration of organic manure (vermicompost) with chemical fertilizers triggered the activities of major soil enzymes such as urease, phosphatase, protease, dehydrogenase and cellulose in ferralitic alluvial soils (Aparna and Rajendran, 2002).

Srinivas *et al.* (2004) reported that among the different organic manures FYM @10 t ha^{-1} registered significantly higher urease activity in rice than green manure leaves like *Sesbania speciosa* @ 7.5 t ha^{-1}, *Crotalaria juncea* @ 7.5 t ha^{-1} and *Gliricidia maculata* @ 7.5 t ha^{-1} which were on par with one another but significantly higher than control.

Jaun *et al*. (2008) studied the effects of long term combined application of organic and mineral fertilizers on microbial biomass, soil enzyme activities and soil fertility in an alluvial soil and reported that urease activity was significantly higher in the treatments where integrated treatments were used.

The results of studies of Wang *et al.* (2008) showed that long-term application of chemical fertilizers and organic manures increased the activities of urease, invertase and phosphatase in the different soil layers.

Liu *et al.* (2010) working on long term effects of fertilizers and organic manures in a rice soil concluded that there was greater increase in urease activity when organic manure was applied along with inorganic fertilizers.

Lysimeter and laboratory incubation studies of organic and inorganic nutrient sources on enzyme activity in a Varanasi soil by Rai and Yadav (2011) revealed that integrated nutrient use resulted in greater urease activity.

The results of a long term fertilizer experiment conducted at G.B. Pant University of Agriculture and Technology maximum urease activity for application of 100 per cent NPK+FYM showed (Babita *et al*., 2012)

Siddeswaran *et al*. (2012) conducted a study on long term effect of nutrient sources on the productivity of rice under organic farming and found that enzyme activities of soil increased with the practice of green manuring and combined application of organic manures.

Datt *et al*. (2013) studied the impact of organic, inorganic and integrated use of nutrients on the soil properties of an acid alfisol under a crop of French bean and reported that urease activity varied from 2.6 to 5.9 μg g^{-1} min^{-1}. The value was significantly higher in the treatments where chemical fertilizer and integrated treatments were used.

2.1.3.2 Phosphatase

Harrison (1983) reported a positive relation between phosphatase activity and organic matter content since the enzyme was seen bound to humic-protein complex. The environmental factors such as soil pH, moisture, surface charges and redox condition at microsite level are of crucial importance for activity of various forms of phosphatase (Nannipieri, 1984).

McLaren (1985) observed a negative correlation for phosphatase level with clay and silt contents in soils. Ladd (1985) reported high levels of phosphatase activity in the rhizosphere which can be attributed to high microbial activity promoted by plant residues.

Haussling and Marschnner (1989) also reported higher activity of phosphatase in rhizosphere than in bulk soil. Partial inhibition of alkaline

phosphomonoesterase was due to the possible sorbtion of the enzyme on humic substances as reported by Kandeler (1990).

Greater activity of acid phosphatase in abandoned agricultural soils that had been enriched with P fertilizers was reported by Collins *et al.* (1992). The activity of phosphatase varied in different soils according to Adams (1992).

Chhonkar and Tarafdar (1994) noticed a positive correlation between phosphatase activity and organic matter. The factors such as plant age and soil moisture affected the usefulness of acid phosphatase in predicting grain yield and plant P status.

Jose *et al.* (1997) found that factors like organic matter and moisture served to be important determinants of the distribution of phosphatase in moderately well and somewhat poorly drained soils. Increase in alkaline phosphatase activity with the addition of ammonium citrate was observed by Gangnon *et al*. (1997).

Baligar *et al*. (1998) observed a decline in phosphatase activity with increasing sampling depth which was attributed to the low organic matter content.

In a long term study on enzyme activities at soil-litter interface of loamy sand, Kandler *et al*. (1999) found that application of NPK fertilizers with FYM increased enzyme activities. The phosphatase activity was also closely related to the microbial biomass C content as reported by Parham *et al*. (2002).

Addition of organic amendments was found to stimulate microbial production of enzymes such as phosphatase and dehydrogenase and enhance organic matter decomposition and organic P mineralization (Garciagill *et al.,* 2000; Takeda *et al.,* 2009).

Krishnakumar *et al.* (2005) and Krishnamurthy *et al*. (2011) reported higher phosphatase activity in organic manure amended rice soil.

Chen *et al.* (2009) opined that soil alkaline phosphatase activity was significantly and positively correlated with soil microbial biomass and dehydrogenase and urease activities, but negatively with soil pH.

Verma and Mathur (2009) from an experiment on rice soil reported that minimum phosphatase activity was recorded in control and maximum in integrated nutrient management treatment plots where organic, inorganic and biofertilizers were used.

2.1.3.3 Dehydrogenase

Dehydrogenase is an oxidoreductase enzyme that exists only in viable cells and is considered a sensitive indicator of soil quality.

According to Briton (1989) addition of farm manures annually for 18 years to a Swedish soil under a wheat-clover-grass-potato rotation increased both the dehydrogenase activity and soil respiration as a result of increased microbial population.

Schuster and Schroder (1990) reported that sequential application of chemicals or xenobiotics could exhibit stronger side effects testimonised by the behaviour of dehydrogenase activity and microbial biomass. Martens *et al*. (1992) found an increased activity of dehydrogenase, urease and phosphatase in alfisols by the application of poultry manure and plant residues.

Bardgett *et al*. (1994) developed an index which allows the quanification of the toxic effects of chemicals by integrating the values obtained from the measurement of parameters like dehydrogenase activity, microbial load and CO_2 evolution rate.

In a long-term field experiment, Albiach *et al.* (2000) found increase in the activities of selected enzymes like dehydrogenase, alkaline phosphomonoesterase, phosphodiesterase, arylsulphatase and urease in soil after the use of organic amendments.

Aparna (2000) reported that application of organic amendments such as vermicompost in combination with lime and fertilizers recorded higher activities of dehydrogenase, urease, phosphatase, protease and cellulose in an alluvial soil than that by FYM or green leaf manure.

Gopalaswamy and Kannaiyan (2000) reported that the dehydrogenase activity is the indicator of microbial activity in the soil. Increase in dehydrogenase due to FYM and vermicompost application was mainly attributed to the increase in organic carbon content which enhanced the microbial population in turn.

Srinivas and Saroja (2002) reported that the addition of organic manures such as FYM at 10 t ha^{-1} caused significant differences in dehydrogenase activity in planted rice in a submerged vertisol.

From a field experiment conducted to investigate the long term effect of fertilizers, FYM treatments and three physiological stages of wheat growth on dehydrogenase activities in soil Mandal *et al*. (2006) reported that dehydrogenase activity was significantly higher in the dough stage of crop (16.3 mg TPF kg^{-1} h^{-1}) than in the flowering (14.0 mg TPF kg^{-1} h^{-1}) stage of wheat. Mean values for dehydrogenase activity ranged from 13.1 mg TPF kg^{-1} h^{-1} in control to 19.7 mg TPF kg^{-1} h^{-1} in 100 per cent NPK+FYM.

Dehydrogenase activity is known to have strong correlation with soil organic C content and thus addition of FYM resulted in more soil dehydrogenase activity a study conducted by Madejon *et al*. (2007).

Bhattacharyya *et al*. (2008) reported that long term applications of FYM @ 10 t ha^{-1} + 100 per cent NPK recorded significantly higher dehydrogenase activity compared to all other treatments. The increase in dehydrogenase activity due to this treatment was 18.6 and 8.9 per cent respectively over 100 per cent NPK and 150 per cent NPK treatments through mineral fertilizers alone.

Verma and Mathur (2009) reported that dehydrogenase enzyme activity was significantly higher for organic and integrated treatments than the chemical.

Nath and Yadav (2011) observed that organic sources produced the maximum dehydrogenase and alkaline phosphatase activity in a soil.

2.1.4 Soil Respiration

Soil respiration reflects the intensity of the soil organic matter decomposition, mineralization and the incidence of the microorganisms in soil, and it is often used for the microbial biomass determination in soils (Anderson and Domsch, 1990).

According to Rowell (1981) the most active respiration occurs in organic-rich, moist, well- structured soils.

Briton (1989) reported that addition of farm manure annually for 18 years to a Swedish soil under a wheat- clover- grass- potato rotation increased both the soil respiration and dehydrogenase activity thus indicating a high microbial population.

Fresh plant compost application accelerates rapid decomposition thereby, increasing microbial respiration (Coyne, 1999) which was found to increase with increase in the soil moisture level.

Tilak *et al*. (1999) observed that continuous application of green manure in a rice-wheat cropping system in some Delhi soils resulted in higher microbial activity in terms of CO_2 evolution.

Liang *et al*. (2003) studied the soil enzymatic activity and growth of rice and barley as influenced by organic manures in an anthropogenic soil and reported that microbial respiration was minimum in the control and maximum in the organic treatments.

From a long term fertilizer experiment in a heavy acid sulphate soil Minh (2003), reported that at one day after incubation (DAI), CO_2 concentrations

ranged from 345 to 669 mg CO_2 kg^{-1}air dry soil and at 14 DAI, from 1.885 to 2.867 mg CO_2 kg^{-1} air dry soil.

Surekha *et al.* (2004) reported that residue addition promotes a stable supply of carbon and energy for microorganisms and cause an increase in the microbial biomass C pool.

Manna *et al*. (2005) studied the long term effect of fertilizers and manure application on soil quality, organic carbon storage and crop yield of some sub humid tropical soils and reported that application of N alone or with P led to decline in soil respiration and organic carbon which improved with addition of N, P, K or NPK+ FYM.

Bedi and Dubey (2009) reported that combination of FYM with inorganic fertilizers resulted in higher microbial respiration. Nair (2010), on the basis of work on standardization of microbial techniques in soil opined that a high CO_2 flux is indicative of high level microbial activity in soil and hence better soil quality.

Babita *et al*. (2012) on the basis of results of long term fertilizer experiments at Pant University of Agriculture and Technology reported that for soil respiratory activity, a treatment of 100 per cent NPK + 15 t ha^{-1} FYM showed an increase of 40.5 per cent over 100 per cent NPK, 26.2 per cent over 150 per cent NPK and 111.5 per cent over 100 per cent NP fertilizers.

Datt *et al*. (2013) studied the impact of organic, inorganic and integrated use of nutrients on the yield and quality of French bean and soil properties in an acid alfisol and reported that application of fertilizers alone resulted in lesser microbial respiration in comparison to organic treatments.

2.1.5 Soil Microbial Biomass Carbon

Sakamoto and Oba (1991) observed that the application of organic manures like FYM usually increased the microbial biomass C. Brookes (1995)

reported that microbial biomass C is a sensitive parameter and can be used as an early warning of changes in ecosystem before they are detectable in other ways.

The addition of N, P and K fertilizers with manures almost doubled the microbial biomass C compared to the values in soils treated with inorganic fertilizers alone as opined by Marumoto (1984).

McGill *et al.* (1986) found that the soil microbial biomass is a source and sink for plant nutrients and an active participant in nutrient cycling thus serving as a fertility factor. Powlson *et al.* (1987) suggested that changes in amounts of microbial biomass C can be used as an early indicator of changes in total soil organic matter content.

Haider *et al*. (1991) observed an increased C:N ratio due to application of cowdung along with oil cakes, resulting from an increased microbial biomass C and activity of urease and dehydrogenase. The use of microbial biomass, dehydrogenase and alkaline phosphatase activity to obtain a more complete and precise definition of soil fertility was suggested by (Beyer *et al*., 1992).

Goyal *et al*. (1992) from their study on buildup of microbial biomass with continuous use of inorganic fertilizers and organic amendments reported that biomass carbon contents ranged from 176 μg C g^{-1} soil to 98 μg C g^{-1} soil. The contents in integrated treatments were significantly higher than chemical fertilizer treatments.

Soil microbial biomass C and enzyme assays seemed to be better indicators of cropping histories than the other methods tested in long term experimental plots as suggested by Jordan *et al.* (1995).

Swarup (1998) found that the use of organic manures like FYM and compost in combination with inorganic fertilizers on long term basis supports carbon sequestration in soils through addition of increased amounts of biomass. A similar trend in biomass accumulation to the tune of 228 per cent as a result of

combined application of chemical fertilizer and organic manures was reported by Delate *et al*. (1999) in soils of Iowa state farm.

Integrated use of inorganic fertilizers and organic manures brings in more microbial biomass C in soil compared to exclusive inorganic fertilizer applications (Goyal *et al*., 1999). Maheswarappa *et al.* (1999) opined that organic amendments produce more microbial biomass than inorganic fertilizers because they increase the proportion of labile carbon and nitrogen there by directly stimulating the activity of microorganisms.

There was a significantly higher microbial biomass C (119 mg g^{-1} soil) in soil receiving FYM alone or FYM along with inorganic fertilizers over 100 per cent NPK fertilization alone (Lalande *et al*., 2000).

Amendments of organic material input through FYM provide organic substrates to the soil which stimulate the microbial growth and activity (Kanchikerimath and Singh 2001).

Elevated CO_2 concentration significantly increased the microbial biomass C when N @ 90 kg ha^{-1} was supplied to a rice soil (Zong *et al*., 2004). hundred per cent N alone and control treatments recorded lower values of microbial biomass C than 100 per cent NPK (Selvi *et al*., 2004).

Application of chemical fertilizers and organic manures showed marked improvement in soil biomass C. The integration of both showed significant increase in biomass C than sole application as well as control (Saini *et al*., 2004).

According to Graham and Haynes (2005) the major indicators of microbial functional pool include microbial biomass C and activities of exo-cellular enzymes involved in the transformations of C (amylase, cellulase and invertase), N (protease) and P (phosphatases).

Manna *et al*. (2005) studied the long term effect of fertilizer and manure application on soil fertility, organic carbon storage and crop yield of some sub humid tropical soils and opined that the application of N alone or with P led to

decline in soil biomass carbon and nitrogen which improved with the addition of N, P, K or NPK+ FYM.

Results of long term fertilizer experiments in an acidic red loam soil at Ranchi indicated the beneficial effects of application of fertilizer and organic matter on the soil microbial biomass contents of C, N, P and S which were higher with balanced fertilization and improved with integrated use of FYM (Mahapatra *et al*., 2007).

Bhattacharyya *et al*. (2008) reported that long term applications of NPK + FYM @ 10 t ha^{-1} recorded significant increase in soil biological properties *viz.,* soil microbial biomass C, soil microbial biomass N and dehydrogenase activity to the extent of 8.8, 9.3 and 9.0 per cent respectively as compared to 50 per cent NPK through chemical fertilizers without organics.

As per the findings of Singh (2010) microbial population, microbial biomass C and N can be considered as good indices of soil health on the basis of results of long term experiments in a rice-rice cropping sequence. Similar results were reported by More (2010) as general conclusion that can be drawn from studies in several soils.

Babita *et al*. (2012) based on long term fertilizer experiments at G.B. Pant University of Agriculture and Technology reported that the soil microbial biomass C was found to increase by 24.1 per cent with the integrated use of 100 per cent NPK and FYM over 100 per cent NPK fertilizers alone.

Datt *et al*. (2013) studied the impact of organic, inorganic and integrated use of nutrients on the soil properties of an acid alfisol soil under French bean and reported that the content of biomass carbon was the highest under organic treatment followed by integrated nutrient management.

2.1.6 Carbon Mineralisation Potential

Prasad and Singh (1980) observed that soil organic carbon content increased with continuous use of FYM in a long term fertilizer experiment at Ranchi under wheat maize rotation.

Wasnik *et al*. (1981) observed that in a vineyard soil the organic carbon content increased from the initial value of 0.39 to 0.64 per cent in surface and from 0.30 to 0.52 per cent in the subsurface soil samples due to the continuous use of fertilizers, but there was no differential effect of increasing doses of fertilizers.

Based on studies conducted in soils under permanent manurial trials at RARS, Pattambi and Kayamkulam, Kurumthottical (1982) reported that application of organic matter either alone or in combination with inorganic fertilizers significantly enhanced the level of soil organic carbon content and its mineralisation.

Joshi *et al*. (1983) from a permanent manurial trial on red sandy loam under coconut reported that the cultivated plots with organic and inorganic fertilization had higher organic carbon build up and mineralisation over non fertilized plots with crop stand.

Prasad *et al*. (1983) observed that addition of chemical fertilizers did not show significant differential effect on organic carbon status of a red loam soil of Ranchi in a long term fertilizer experiment with soybean- potato-wheat rotation.

Pushpangadan (1985) reported that organic carbon status of the soil was not influenced by continued NPK fertilization in a long term fertilizer experiment under coconut at Balaramapuram.

Rabindra and Honnegowda (1986) revealed that continuous use of FYM and judicious combination of organics and inorganics enhanced the soil organic carbon content from 0.46 to 0.81 per cent in a long term fertilizer trial with sugarcane in a red sandy loam soil.

Sharma *et al.* (1987) observed that in a permanent manurial experiment on the continuous application of inorganic fertilizers and organic manures to plots for 14 years, the FYM application either alone or in combination with inorganic fertilizers enriched the soil with total organic carbon.

Varma *et al*. (1987) conducted a study to assess the fertility status of soils subjected to continuous use of graded level of fertilizers for rice and wheat and found depletion of organic carbon with increased levels of N and P.

Aggarwal and Venkateswarlu (1989) observed that long term application of manure alone or in combination with chemical fertilizers increased the organic matter status and carbon mineralisation in soil.

In a field study in a dryland vertisol soil Muthuvel *et al.* (1989) observed that annual addition of FYM to fixed rotation of cotton- pearl millet to supply 40 Kg N ha^{-1} markedly increased the organic carbon content of soils.

Sarkar *et al*. (1989) reported that the cumulative effect of long term use of chemical fertilizers on organic carbon content and its mineralisation potential of the ploughed layer was relatively less compared to continuous incorporation of FYM.

Janzen (1991) based on long term crop rotation studies in a soil of Alberta opined that moderate application of nitrogenous and phosphatic fertilizers can increase surface soil organic carbon content and there by the soil organic matter.

Alokkumar and Yadav (1993) found that the soils of unfertilized plots showed reduction of about 50 per cent in organic carbon by 12 years of cropping as compared with initial value.

Study on the effect of organic amendments on biological properties of a soil under winter wheat and barley by Ross *et al*. (1995) revealed an increase in soil organic matter content and soil enzyme activities as a result of rhizo-deposition.

Gopalaswamy and Kannaiyan (2000) found out that *Azolla* application significantly improved the soil organic carbon status in wet soil. Dhiman *et al.* (2000) reported that incorporation of crop residues of both paddy and wheat increased the organic carbon mineralisation of soil.

Selvi *et al.* (2003) observed that the highest organic carbon values were recorded in plots where fertilizers were continuously incorporated with FYM. Ramesh and Chandrasekaran (2004) reported a gradual mineralisation pattern of organic carbon content when *Sesbania rostrata* was incorporated in situ at flowering stage in rice- rice cropping system.

In a long term fertilizer experiment Subehia *et al.* (2005) observed that the fertilizer treatments had significant influence on the soil organic matter status and its mineralisation. It varied from 9.4 g kg^{-1} soil for 100 per cent N treatment to 12.8 g kg^{-1} soil for NPK + FYM treatment.

Verma *et al*. (2005) studied the effects of continuous cropping and fertilization in a rice-wheat cropping sequence in a typic haplustept and suggested that 100 percent recommended NP with FYM @ 10 t ha^{-1} was the superior treatment in terms of improving soil organic carbon.

Rudrappa *et al*. (2006) in a study on long-term manuring and fertilization on soil organic carbon observed that at 0–15 cm soil depth, the highest percent of total C was mineralized under 150 percent NPK + FYM followed by 150 and 100 per cent NPK. However, at 15–30 and 30–45 cm soil depths, the highest percent of total C was mineralized with 100 per cent NP treatment, while the lowest values were from 100 per cent NPK + FYM and 100 per cent NP.

Monaco *et al*. (2008) reported that repeated application of the different organic materials, in addition to urea- N fertilizer, increased not only soil organic carbon content but also microbial biomass C when compared to soil that received no fertilizer N and soil that received urea alone.

Vineela *et al.* (2008) observed that soil organic carbon levels increased considerably due to long-term fertilization and/or manuring for 29 years in some vertisol and alfisol soils under semi-arid climatic condition.

Zhang *et al*. (2009) summarized the results of nine long term experiments conducted across different agro-ecological regions of China. They found that compared with NPK, the combined application of NPK and FYM resulted in a higher increase in soil organic carbon in the maize and wheat-maize systems than in rice and rice-wheat systems.

Mohanty *et al*. (2012) studied the carbon mineralisation kinetics of soil under 41 years of rice-rice system under different nutrient management practices and reported that potentially mineralisable carbon ranged from 1016 to 1855 mg kg^{-1} soil.

From a study of the effect of integrated nutrient management on organic carbon and nutrient balance sheet in a rice-rice cropping system in an acid lateritic soil under long term fertilizer experiment at RARS, Pattambi, Moossa *et al.* (2012) reported that the organic carbon contents in soil in 100 per cent NPK+ FYM plot and that in 100 per cent NPK+ *In situ* green manured (daincha) plot were higher than that of the plot receiving inorganic nutrients alone.

Siddeswaran *et al*. (2012) conducted a study on the long term effect of nutrient sources on the productivity of rice under organic farming and found that soil organic carbon content improved with combined application of organic manures and green manuring compared to organic manure alone.

2.1.7 Nitrogen Mineralisation Potential

Muthuvel *et al.* (1977) observed that the soil available N was positively influenced by the addition of organic matter under rainfed condition in a permanent manurial trial at Coimbatore.

Tiwari *et al*. (1980) studied the beneficial effects of green manuring alone and in combination with fertilizer N in rice and observed that the interaction effect of green manuring and N mineralisation was positive and significant.

The application of balanced fertilizers at 100 percent of the recommended dose and above resulted in mineralisation of soil N whereas considerable decrease was noticed in soils which had not been fertilized with N for more than 12 years in the long term fertilizer experiment conducted at various locations in India (Nambiar, 1985).

In a long term fertilizer experiment with wheat, Gupta *et al.* (1988) observed an increase in available N content of soil up to 20 days after FYM application and a decrease thereafter.

Harris *et al.* (1994) found that N mineralisation was the greatest in the manure amended soil suggesting that treatment resulted in a viable soil biomass which was either larger in size or metabolically more active.

Goulding *et al*. (2000) observed larger N leaching loss from the plots treated with FYM in his experiment on red soil which he reasoned that after over 150 years of application, the soil organic matter had more than doubled, and the amount of N from mineralization was very large.

From the results of long term fertilizer experiment on vertisols Subehia *et al.* (2005) reported that application of 100 percent NPK + FYM recorded significantly higher available N over 100 per cent NPK alone during all the years and that the increase in FYM treated plots was due to mineralization of FYM.

From a field experiment conducted to investigate the long term effect of fertilizer and FYM and three physiological stages of growth on N mineralisation in a wheat soil. Mandal *et al*. (2006) reported that mineralisable N in soil was the highest (105.8 mg kg^{-1}) at tillering stage of the crop and that mean values for mineralisable N ranged from 78.5 mg kg^{-1} soil in control to 8 mg kg^{-1}soil in 100 per cent NPK+FYM.

Based on a study on mineralisation dynamics and biochemical propert*ie*s following application of organic residues to an alfisol soil, Mondini *et al*. (2010) reported that animal by product caused a significant increase in the content of mineral N and water soluble C.

Mohanty *et al*. (2012) studied the carbon mineralisation kinetics of a rice soil under 41 years of rice-rice system under different nutrient management practices and reported that the values of potentially mineralisable N at field capacity ranged from 44.5 to 59.4 mg kg^{-1} soil and from 18.8 to 29.2 mg kg^{-1} soil in 0-15 cm and 15-30 cm depth soils respectively.

Saravanapandian and Haroon (2012) studied the influence of continuous application of organic manures and inorganic fertilizers on rice yield in a permanent manurial rice monoculture in a soil of Madurai Agriculture College and reported that application of green leaf manure significantly influenced the rice grain yield and that the highest grain yield of 6780 kg ha^{-1} was registered with the application of green leaf manure conjointly with N, P and K.

Siddeswaran *et al*. (2012) conducted a study on long term effect of nutrient sources on the productivity of rice in a soil under organic farming and found that available N status steadily improved with green manuring and poultry manure application compared to control and green manure alone.

2.1.8 Hot Water Extractable Carbohydrates

Haynes *et al.* (1991) found that the fraction of soil carbohydrate extractable with hot water was more closely correlated with aggregate stability than total soil organic matter content.

Haynes and Beare (1996) suggested that carbohydrate content of hot water extracts of soils may be used as an index of soil quality, particularly in relation to soil aggregation.

According to Banwasi and Bajpai (2001) a balanced fertilizer dose of 100 per cent NPK significantly improved the water soluble carbohydrates over the control indicating that balanced use of fertilizers resulted in better establishment of root system of plants and also increased microbial activity in soil.

Kasia *et al*. (2002) on the basis of a study on carbohydrates in hot water extracts of soil aggregates as influenced by long-term management reported that management practices that increased soil organic matter also increased soil carbohydrate concentrations.

According to Debosz *et al*. (2002) and Xiao *et al*. (2006) the general trend of the hot water soluble carbohydrates concentrations indicated a general increase of this fraction in soils under different cropping systems.

The hot water soluble carbohydrates, being a component of the labile pool of soil organic carbon and also being closely related to soil microbial biomass aggregation could be used as one of the soil quality indicators in soil plant ecosystems (Ghani *et al.,* 2003).

Studies by Gilani and Bahmanyar (2008) showed that water soluble carbohydrates and enzyme activity for 100 per cent NPK addition to soils were significantly higher than 100 per cent N alone, whereas it was non- significant with respect to 100 per cent NP addition and also observed a positive correlation between soil enzyme activity and water soluble soil carbohydrates.

From long term field experiments in a South West England soil Hazarika and Parkinson (2011) reported that estimation of water soluble soil carbohydrates could be regarded as the most sensitive measurement for determining the impact of long term nutrient application and residue management in soils.

Materials and Methods

3. MATERIALS AND METHODS

The present study on "Biological profile of ferralitic alluvial paddy soils under long term differential fertilizer application" was formulated with the objective of studying the variations in the important biological properties of ferralitic alluvial soils under long term fertilizer experiments with rice-rice cropping sequence. The soils of three long term fertilizer experiments at RARS, Pattambi (listed below) formed the study material.

1) Permanent Manurial Trial with Tall indica rice variety (PMT- Tall)

2) Permanent Manurial Trial with Dwarf indica rice variety (PMT- Dwarf)

3) AICRP on long term fertilizer experiments (LTFE)

The details of the field experiments from which the soil samples were collected, the laboratory analytical methods followed and statistical techniques adopted for rational interpretations of the results are discussed in this chapter.

3.1 DETAILS OF FIELD EXPERIMENTS AT RARS, PATTAMBI

The Permanent Manurial Trials and the All India Co-ordinated Project on long term fertilizer experiment have been laid out at Regional Agricultural Research Station, Pattambi and are being continued with the main objectives of studying the effect of continuous application of plant nutrients (NPK) in organic, inorganic forms and in combinations on sustainable production in the rice-rice cropping sequence being practiced there. The first permanent manurial trial with tall indica rice variety was started in Kharif, 1962 (Plate1) and the second permanent manurial trial with dwarf indica rice variety, in Kharif, 1972 (Plate2). The AICRP on long term fertilizer experiment was initiated in Kharif 1997 (Plate 3). The study area, Pattambi is located at $10^{0}48^{1}16^{11}$ North latitude and $76^{0}11^{1}00^{11}$ East longitude. Based on agro ecological classification (NBSS &LUP, 2012) Pattambi is located in AESU (3) – Laterite terrain/AEU (10) – North central laterite/ AEZ (2) - Mid land laterites.

The technical programme of the three experiments are as follows.

3.1.1 Permanent Manurial Trial (Tall indica)

Design : Randomised Block

No. of replications : 4

Variety : PTB 2 (Ponnaryan) – Kharif

PTB 20 (Chuvannachitteni)- Rabi

Plot size : 25 m^2

Treatments : 8

T_1 : 40 kg N ha^{-1} as cattle manure

T_2 : 40 kg N ha^{-1} as green leaf

T_3 : 20 kg N ha^{-1} as cattle manure + 20 kg N ha^{-1} as green leaf

T_4 : 40 kg N ha^{-1} as ammonium sulphate

T_5 : 20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_6 : 20 kg N ha^{-1} as green leaf+ NPK @ 20:20:20 kg ha^{-1}

T_7 : 10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_8 : NPK @ 40:20:20 kg ha^{-1}

3.1.2 Permanent Manurial Trial (Dwarf indica)

Design : Randomized Block

No. of replications : 4

Variety : Jaya (Both Kharif and Rabi)

Plot size : 40 m^2

Treatments : 8

T_1 - 90 kg N ha^{-1} as cattle manure

T_2 - 90 kg N ha^{-1} as green leaf

T_3 - 45 kg N ha^{-1} as cattle manure + 45 kg N ha^{-1} as green manure

T_4 - 90 kg N ha^{-1} as ammonium sulphate

T_5 - 45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_6 - 45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}

T_7 - 22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure +NPK @ 45:45:45 kg ha^{-1}

T_8 - NPK @ 90:45:45 kg ha^{-1}

3.1.3 AICRP on long term fertilizer experiment

Design	:	Randomized Block
No. of replications	:	4
Variety	:	Aiswarya (Both Kharif and Rabi)
Plot size	:	125 m^2
Treatments	:	12

T_1 : 50 percent NPK (as per KAU POP recommendation)

T_2 : 100 percent NPK

T_3 : 150 percent NPK

T_4 : 100 percent NPK + lime @ 600 kg ha^{-1}

T_5 : 100 percent NPK + $CuSO_4$ @ 5 kg ha^{-1} (if deficiency symptoms appear)

T_6 : 100 percent NP

T_7 : 100 percent N

T_8 : 100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_9 : 50 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_{10} : 100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)

T_{11} : 50 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)

T_{12} : Absolute control (No fertilizer)

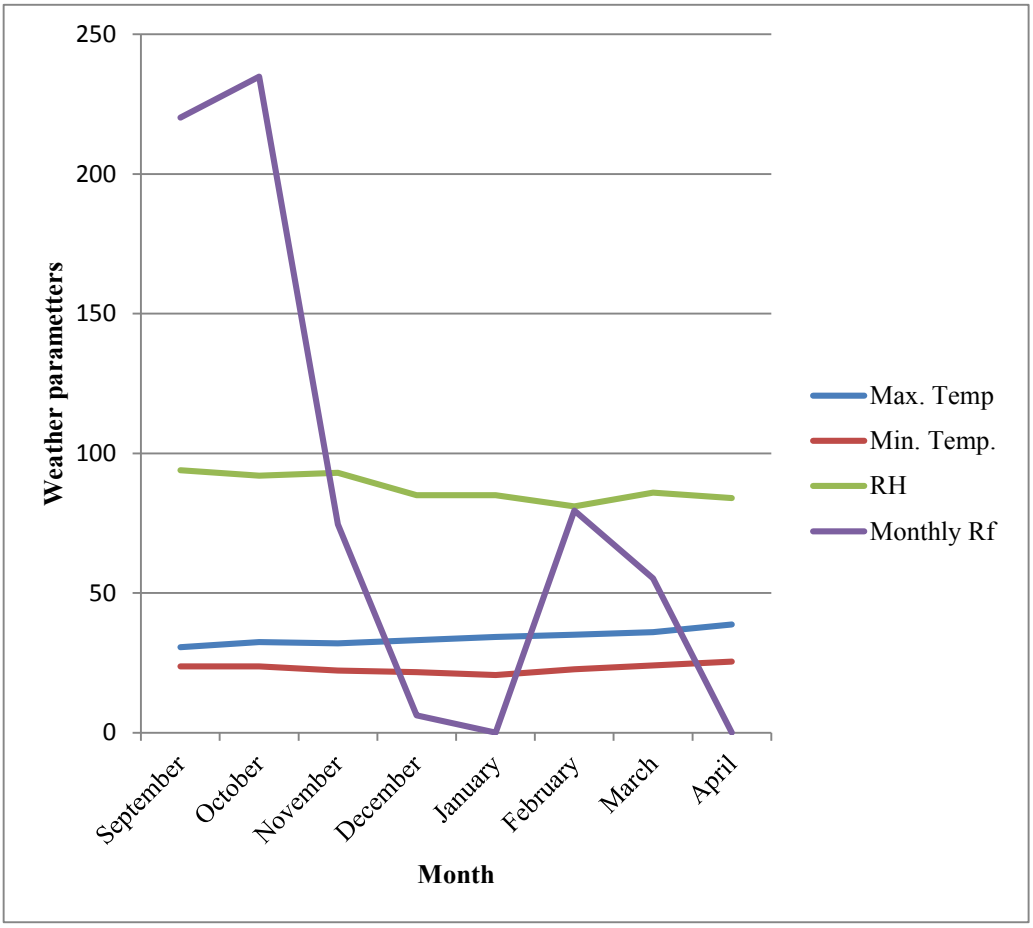
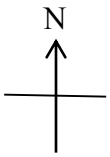
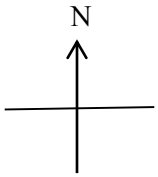


Figure 1. Weather parameters during field experiment



R_1			R_2			R_3			R_4	
T_3	T_4		T_6	T_8		T_5	T_6		T_8	T_7
T_2	T_6		T_4	T_1		T_7	T_8		T_3	T_1
T_1	T_7		T_3	T_5		T_1	T_3		T_5	T_4
T_5	T_8		T_2	T_7		T_2	T_4		T_2	T_6

Figure 2. Layout of PMT (Tall) experimental plot



R1					R2			
T8	T5	T1	T7		T4	T2	T1	T3
T6	T2	T3	T4		T7	T8	T5	T6
R3					R4			
T7	T2	T3	T5		T2	T6	T4	T5
T1	T4	T6	T8		T3	T1	T7	T8

Figure 3. Layout of PMT (Dwarf) experimental plot

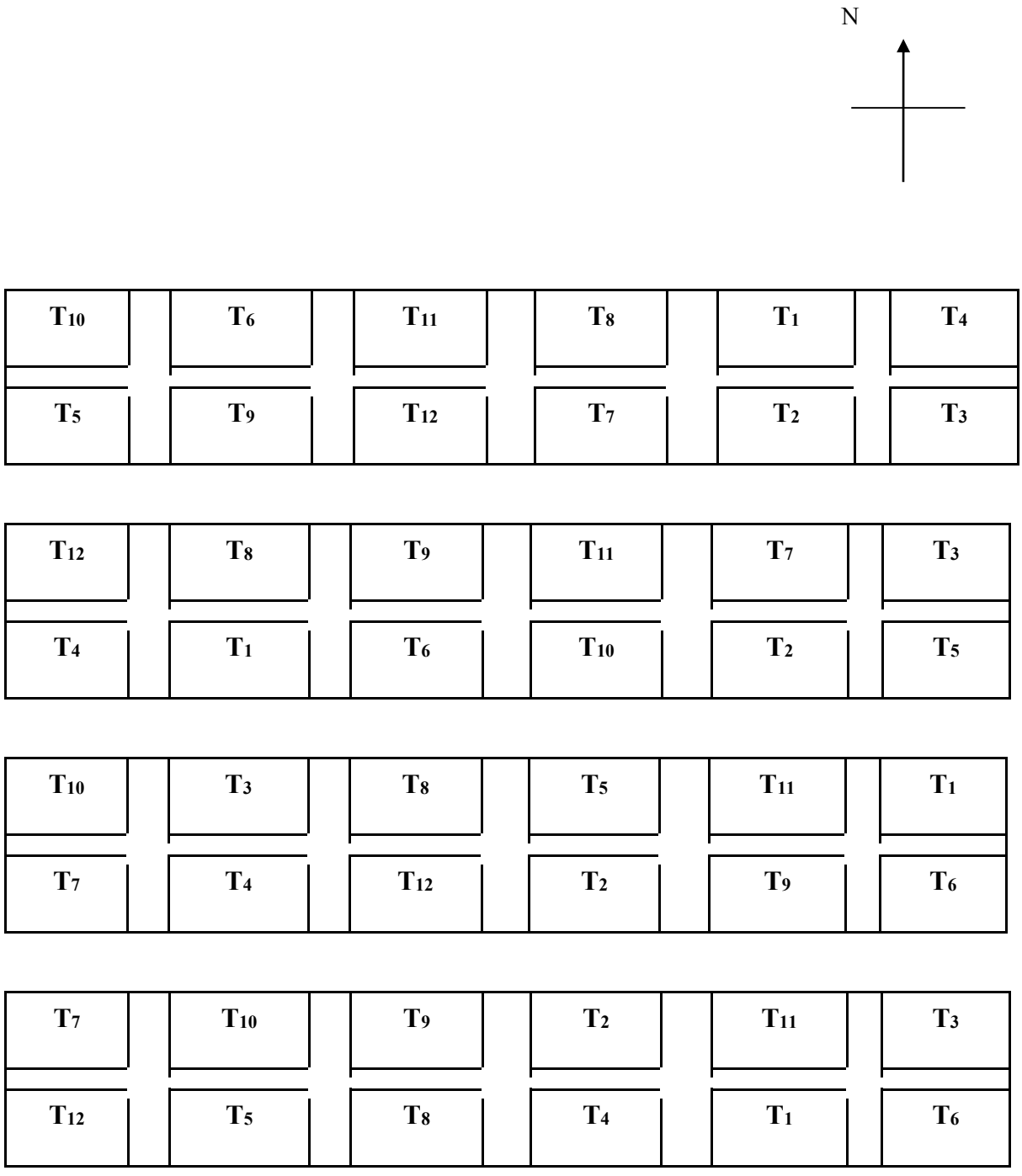


Figure 4. Layout of LTFE experimental plot

Plate 1. Field view of permanent manurial trial with Tall indica rice variety

Plate 2. Field view of permanent manurial trial with Dwarf rice variety

Plate 3. Field view of long term fertilizer experiment

3.2 COLLECTION OF SOIL SAMPLES

Soil samples were collected from each plot of the above three experiments immediately after the harvest of the 2012-13 kharif crops of the respective experiments. Surface soil samples up to a depth of 0-15 cm were collected using a soil tube specially fabricated for this purpose. The tubes were of 30 cm in length with a handle at the top, having an internal diameter of 5 cm. The soil tubes are hammered into the soil to a depth of 15 cm. The tubes were taken out, the soil inside was pushed out and packed in polythene bags.

3.2.1 Preparation of Soil Samples for Analysis

As all the soil characters studied are related to the biological activities in the soil, field fresh soil samples were used for analysis which were maintained at field moisture capacity under refrigeration and air dried wherever necessary.

3.2.2 Soil Macro Fauna

3.2.2.1 Earthworm Population

This estimation was done *in situ.* Immediately after the harvest of the plants the top soil in one square metre area of land in each plot was dug out and spread on a sheet of paper. The number of earthworms present in this soil was counted.

3.2.2.2 Microarthropods

Microarthropods were extracted from the soil samples using modified Berlese-Tullgren funnel extractor (Macfadyen, 1961). One kg soil sample was taken and placed over a wire guaze over a steep sided funnel. Soil was heated gently using 40 watts bulb. Heating was continued for a day. The arthropods moved down in response to the temperature gradient created and eventually got collected in a collecting vial containing ethanol-water mixture kept at the tail of the funnel. The content of the collecting vial was directly transferred to a counting dish and their population counted under a binocular microscope (Plate 4).

Plate 4. A view of the arthropod estimation

Plate 5. A view of the soil respiratory activity study

3.2.3 Soil Microflora

The serial dilution agar plating method outlined by Timonin, (1940) was adopted for the isolation and enumeration of the following microorganisms, which were cultured on suitable media as shown below.

3.2.3.1	Bacteria	-	Nutrient agar
3.2.3.2	Fungi	-	Martins' Rose Bengal agar
3.2.3.3	Actinomycetes	-	Ken knight's agar
3.2.3.4	*Azospirillum*	-	Nitrogen free Bromothymol blue (NFB) agar
3.2.3.5	*Azotobacter*	-	Jenson's agar
3.2.3.6	P- solubilizers	-	Pikovaskaya's agar

3.2.4 Soil Enzymes

3.2.4.1 Urease Activity

The urease activity was determined following the method described by Broadbent *et al*. (1964).

Twenty five gram soil was weighed into an Erlenmayer flask, to which 4 ml of urea substrate solution was added. Enough water was added to each flask to maintain a tension of 1/3 bar and incubated for 24 hours at 30^0C. Then the flasks were removed, $CaSO_4$ solution was added to make up the volume to 100 ml. About 15 ml of the supernatant was taken and colour was developed by adding 10ml of p-dimethyl amino benzaldehyde which was then read in a spectrophotometer at a wavelength of 420 nm. Standards were also prepared by using urea solutions of known concentrations (Plate 6A).

3.2.4.2 Phosphatase Activity

The phosphatase activity was determined following the procedure described by Eivazi and Tabatabai (1977).

(A)

(B)

(C)

Plate 6. Soil enzyme assay: (A) Urease (B) Phosphatase (C) Dehydrogenase

To one gram soil in a 50 ml Erlen Meyer flask, 0.2 ml toluene, 4 ml modified universal buffer (pH- 6.5) and 1 ml p-nitrophenyl phosphate solution were added and incubated at 23^0C for one hour. After incubation, 0.5 M $CaCl_2$ (1ml) and 0.05M NaOH (1ml) were added. The contents were swirled and filtered through Whatman No.2 filter paper and the intensity of yellow colour developed was read in a spectrophotometer at a wavelength of 420 nm. One percent solution of p- nitrophenyl phosphate was used for the preparation of standards (Plate 6B).

3.2.4.3 Dehydrogenase Activity

Dehydrogenase activity was estimated as per the procedure described by Casida *et al*., 1964.

Six gram of air dried soil was weighed to a 250 ml Erlen meyer flask. One ml of 3 per cent triphenyl tetrazolium chloride was added and incubated for 24 hours at 27°C. After incubation, the soil was quantitatively transferred to a glass funnel and was given ethanol washings consecutively till the volume reached 100 ml. The colour intensity was then read in a Spectrophotometer at 485 nm. A series of standards were used for preparing the calibration curve (Plate 6C).

3.2.5 Soil Respiration

The respiratory activity of the soil samples were estimated using the method proposed by Jenkinson and Powlson (1976), where the CO_2 evolved from a fixed quantity of incubated soil was collected in standard alkali and titrated against standard acid (Plate 5).

3.2.6 Microbial Biomass Carbon

Microbial biomass carbon was determined in the field moist soil by the chloroform-fumigation-extraction method (Vance *et al*., 1987).

3.2.7 Carbon Mineralisation Potential

The chromic acid wet digestion method suggested by Walkley and Black (1934) was employed for the estimation of carbon mineralisation potential of soils.

3.2.8 Nitrogen Mineralisation Potential

Nitrogen mineralisation potential was determined by alkaline permanganate method (Subbiah and Asija, 1956).

3.2.9 Hot Water Extractable Carbohydrates

The hot water extractable carbohydrates in soil samples were determined by Anthrone blue colour method (Brink *et al*., 1960). Five gram of air dry soil was passed through 1 mm sieve and then hydrolysed with 50 ml of 3N H_2SO_4 for 24 h on a steam bath maintained at 85^0C. Hot hydrolysate was passed through a fritted disc filter of medium pore size and residue left on the filter was washed with 50 ml of hot water. The filtrate was allowed to cool to room temperature and volume was made up to 100ml with distilled water. Five ml of diluted soil hydrolysate was mixed with 10 ml of Anthrone reagent and absorbance of green colour was read at 625 nm taking water-anthrone blank. Standard curve was prepared using standard glucose solution.

In addition the data on soil pH, Available P and K pertaining to Kharif. 2013 were collected from the basic records of RARS, Pattambi.

3.3 PLANT CHARACTERS

As the influence of the biological properties of the soils collected during Kharif season of 2013 for study are naturally bound to be reflected on the succeeding crop grown on these soils, the plant characters pertaining to rabi season of 2013 of the three experiments were considered for the study. Data on the following plant characters were collected from the field registers of the respective experiments at RARS, Pattambi as envisaged in the technical programme.

- Plant Height
- Number of Tillers Plant^{-1}
- Number of Panicles Plant^{-1}
- Grain Yield
- Straw Yield

3.4 STATISTICAL ANALYSIS

The data generated from these experiments were subjected to the analysis of variance applicable to randomised block design described by Cochran and Cox (1965) and their significance was tested by the F test (Snedecor and Cochran, 1975). Correlation and multiple regression studies were also carried out to study the degree of association between the various biological properties of soil and grain yield.

Results

4. RESULTS

Laboratory investigations were conducted at College of Agriculture, Vellayani on the post-harvest soil samples (Kharif, 2012-13) of the following three long term fertilizer experiments of RARS, Pattambi to study the variations in the biological properties of the ferralitic alluvial soils there under the influence of different fertility treatments.

1. Permanent Manurial Trial with Tall indica rice variety rice (PMT- Tall)

2. Permanent Manurial Trial with Dwarf indica variety rice (PMT- Dwarf)

3. AICRP on Long Term Fertility Experiments (LTFE)

Data on plant characters of the succeeding Rabi crop (2012-13) of these experiments were collected from that recorded in the field registers of the stations in addition to some soil data relating to Kharif crops (2012-13). The salient results generated out of the studies are presented in this chapter.

4.1 EXPERIMENT NO.1**:** PERMANENT MANURIAL TRIAL (TALL INDICA)

4.1.1 Soil Macrofauna

4.1.1.1 Earthworms

In spite of several attempts on consecutive days, no earthworms could be located in the top soil in any of the plots of the experiment.

4.1.1.2 Arthropods

The effect of treatments on soil arthropod count is given in Table 1. The treatment T_5 (20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest value of 73.00 no. kg^{-1} soil and was statistically on par with T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) (70.75 no. kg^{-1} soil) and T_3 (20 kg N ha^{-1} as cattle manure + 20 kg N ha^{-1} as green leaf) (54.5 no. kg^{-1} soil). Treatment T_8 (NPK @ 40:20:20 kg ha^{-1}) registered the lowest value (37 no. kg^{-1} soil) which was significantly inferior to all other treatments.

Table 1. Effect of treatments on soil macro fauna and micro flora (PMT- Tall)

Treatments	Soil macro fauna	Soil micro flora	
	Arthropod count (no. kg^{-1} soil)	Bacteria (x 10^6 cfu g^{-1} soil)	Actinomycetes (x 10^3 cfu g^{-1} soil)
T_1	44.25	76.50	14.25
T_2	40.00	48.25	12.50
T_3	54.50	64.50	15.50
T_4	37.00	60.75	11.50
T_5	73.00	60.25	13.75
T_6	52.75	71.75	16.75
T_7	70.75	81.75	19.75
T_8	37.00	52.50	10.75
CD $_{(0.05)}$	19.34	10.22	3.67

T_1 : 40 kg N ha^{-1} as cattle manure

T_2 : 40 kg N ha^{-1} as green leaf

T_3 : 20 kg N ha^{-1} as cattle manure + 20 kg N ha^{-1} as green leaf

T_4 : 40 kg N ha^{-1} as ammonium sulphate

T_5 : 20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_6 : 20 kg N ha^{-1} as green leaf+ NPK @ 20:20:20 kg ha^{-1}

T_7 : 10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_8 : NPK @ 40:20:20 kg ha^{-1}

4.1.2 Soil Microflora

4.1.2.1 Bacteria

Various treatments significantly influenced the bacterial counts in the post-harvest soil as observed from Table 1. The mean values ranged from 48.25 x 10^6 cfu g^{-1} soil to 81.75 x 10^6cfu g^{-1} soil. The treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) registered the highest mean value of 81.75 x 10^6 cfu g^{-1} soil, which was on par with T_1 (40 kg N ha^{-1} as cattle manure) (76.5 x 10^6 cfu g^{-1} soil) and T_6 (20 kg N ha^{-1} as green leaf+ NPK @ 20:20:20 kg ha^{-1}) (71.75 x 10^6 cfu g^{-1} soil). The lowest value was recorded by T_2 (20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) (48.25 x 10^6 cfu g^{-1} soil) which was significantly lower than all other treatments.

4.1.2.2 Actinomycetes

Actinomycetes counts in the post-harvest soil are given in Table 1. Maximum population of actinomycetes of 19.75x 10^3 cfu g^{-1} soil was recorded in the treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) which was statistically on par with T_6 (20 kg N ha^{-1} as green leaf+ NPK @ 20:20:20 kg ha^{-1}) (16.75 x 10^3cfu g^{-1} soil). The lowest actinomycetes count was recorded in T_8 (NPK @ 40:20:20 kg ha^{-1}) with mean value of 10.75 x 10^3 cfu g^{-1} soil.

4.1.2.3 Fungi

The fungal population (Table 2.) ranged from 26.00 to 57.00 x10^4 cfu g^{-1} soil. Treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest mean value of 57.00 x 10^4 cfu g^{-1} soil and was found to be on par with treatment T_1 (40 kg N ha^{-1} as cattle manure) (52.00 x 10^4 cfu g^{-1}soil). T_4 (40 kg N ha^{-1} as ammonium sulphate) registered the lowest value of 26 x 10^4 cfu g^{-1}soil.

4.1.2.4 Azospirillum

The various treatments significantly influenced the *Azospirillum* population in the count of soil (Table 2.). The treatment T_3 (20 kg N ha^{-1} as cattle manure + 20 kg N ha^{-1} as green leaf) recorded the highest mean value of 64.25 x

Table 2. Effect of treatments on soil micro flora (PMT- Tall)

Treatments	Soil micro flora			
	Fungi (x 10^4 cfu g^{-1} soil)	*Azospirillum* (x 10^4 cfu g^{-1} soil)	*Azotobacter* (x 10^3 cfu g^{-1} soil)	P solubilizers (x 10^4 cfu g^{-1} soil)
T_1	52.00	45.25	23.50	2.50
T_2	44.75	50.50	28.50	2.25
T_3	39.75	64.25	24.50	0.75
T_4	26.00	35.75	21.75	2.25
T_5	42.00	40.50	23.50	4.00
T_6	44.00	56.50	28.50	2.50
T_7	57.00	53.50	32.25	3.50
T_8	34.00	33.50	13.00	0.75
CD (0.05)	9.78	17.06	6.94	1.39

T_1 : 40 kg N ha^{-1} as cattle manure

T_2 : 40 kg N ha^{-1} as green leaf

T_3 : 20 kg N ha^{-1} as cattle manure + 20 kg ha^{-1} as green leaf

T_4 : 40 kg N ha^{-1} as ammonium sulphate

T_5 : 20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_6 : 20 kg N ha^{-1} as green leaf+ NPK @ 20:20:20 kg ha^{-1}

T_7 : 10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_8 : NPK @ 40:20:20 kg ha^{-1}

10^4 cfu g^{-1} soil. It was on par with the treatments T_6 (56.5 x 10^4 cfu g^{-1} soil), T_7 (53.5 x 10^4 cfu g^{-1} soil) and T_2 (50.5 x 10^4 cfu g^{-1} soil). Treatment T_8 (NPK @ 40:20:20 kg ha^{-1}) registered the lowest mean *Azospirillum* count of 33.5 x 10^4 cfu g^{-1} soil.

4.1.2.5 Azotobacter

Perusal of data revealed that there was significant variation in *Azotobacter* population of postharvest soil (Table 2.). Treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest value (32.25 x 10^3 cfu g^{-1} soil) which was on par with T_2 (40 kg N ha^{-1} as green leaf) (28.5 x 10^3 cfu g^{-1}soil) and T_6 (20 kg N ha^{-1} as green leaf+ NPK @ 20:20:20 kg ha^{-1}) (28.5 x 10^3 cfu g^{-1}soil). Treatment T_8 (NPK @ 40:20:20 kg ha^{-1}) registered the least value (13 x 10^3 cfu g^{-1} soil).

4.1.2.6 P Solubilizers

It can be observed from (Table 2.) that the mean values of phosphorus solubilizers count were in the range from 0.75 to 4.00 x 10^4 cfu g^{-1} soil. Treatment T_5 (20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest mean value of 4.00 x 10^4 cfu g^{-1} soil and was found to be on par with treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) (3.5 x 10^4 cfu g^{-1} soil). The lowest value for phosphorus solubilizers count (0.75 x 10^3 cfu g^{-1}) soil was recorded by both T_8 (NPK @ 40:20:20 kg ha^{-1}) and T_3 (20 kg N ha^{-1} as cattle manure + 20 kg N ha^{-1} as green leaf).

4.1.3 Soil Enzymes

Soil enzymatic assays act as potential indicators of ecosystem quality being operationally practical, sensitive and are integratively described as 'biological finger prints' of past and present soil management. Quantitative measurement of these enzyme activities can contribute to our understanding of transformations by allowing us to evaluate the microbes present in soil. Measurement of activity of extracellular enzymes provides information on the biological activities of microorganisms. The activities of various enzymes such as

Table 3. Effect of treatments on soil enzymes and soil respiration (PMT- Tall)

Treatments	Soil enzymes			Soil respiration (mg CO_2 100 g^{-1} soil d^{-1})
	Urease (µg urea g^{-1} soil hr^{-1})	Phosphatase (µg p- nitrophenol g^{-1} soil hr^{-1})	Dehydrogenase (µg TPF g^{-1}soil 24 hr^{1})	
T_1	147.25	30.38	282.56	6.86
T_2	183.35	34.28	233.47	7.31
T_3	226.68	39.53	249.95	6.74
T_4	274.02	35.73	318.77	6.11
T_5	344.18	34.48	344.83	7.64
T_6	286.25	34.95	432.01	6.77
T_7	363.68	44.83	527.17	7.09
T_8	273.03	38.55	205.11	5.42
CD (0.05)	12.47	7.41	20.00	0.74

T_1 : 40 kg N ha^{-1} as cattle manure

T_2 : 40 kg N ha^{-1} as green leaf

T_3 : 20 kg N ha^{-1} as cattle manure + 20 kg N ha^{-1} as green leaf

T_4 : 40 kg N ha^{-1} as ammonium sulphate

T_5 : 20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_6 : 20 kg N ha^{-1} as green leaf+ NPK @ 20:20:20 kg ha^{-1}

T_7 : 10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_8 : NPK @ 40:20:20 kg ha^{-1}

dehydrogenase, urease and phosphatase in soils were assayed and are presented in Table 3.

4.1.3.1 Urease

It is observed from the Table 3 that the treatments had significant effect on urease activity. The mean values of urease activity ranged from 147.25 to 363.675 µg urea hydrolysed g^{-1} soil hr^{-1}. The highest value was recorded for the treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) (363.675 µg urea hydrolysed g^{-1} soil hr^{-1}) which was found to be significantly superior to other treatments. Treatment T_1 (40 kg N ha^{-1} as cattle manure) recorded the lowest value for urease activity (147.25 µg urea hydrolysed g^{-1} soil hr^{-1}) which was significantly lower than all other treatments.

4.1.3.2 Phosphatase

It is observed from the Table 3 that the treatments had significant effect on phosphatase activity. The highest value of phosphatase activity was noticed for the treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) (44.83 µg p- nitrophenol released g^{-1} soil hr^{-1}) which was statistically on par with T_3 (39.53 µg p- nitrophenol released g^{-1} soil hr^{-1}) and T_8 (38.55 µg p-nitrophenol released g^{-1} soil hr^{-1}). The lowest value of 30.38 µg p- nitrophenol released g^{-1} soil hr^{-1} was noticed for the treatment T_1 (40 kg N ha^{-1} as cattle manure) which was on par with the treatment T_2 (34.28 µg p- nitrophenol released g^{-1}s oil hr^{-1}), T_4 (35.73 µg p-nitrophenol released g^{-1} soil hr^{-1}), T_5 (34.48 µg p- nitrophenol released g^{-1} soil hr^{-1}) and T_6 (34.95 µg p- nitrophenol released g^{-1} soil hr^{-1}).

4.1.3.3 Dehydrogenase

Statistical analysis of data on dehydrogenase activity indicated a high significant effect due to treatments (Table 3). The mean value ranged from 205.11 to 527.17 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}.The highest values was recorded for the treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) (527.17 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}) which was found to be significantly superior to all other treatments. The

treatment T_8 (40 kg N ha^{-1} as cattle manure) recorded the lowest value for the dehydrogenase activity (205.11 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}) which was significantly lower than all other treatments.

4.1.4 Soil Respiratory Activity

The results pertaining to the analysis for the respiratory activity of postharvest soil samples are presented in Table 3. Application of various treatments significantly influenced soil respiratory activity. The mean values ranged from 5.42 to 7.64 µg CO_2 evolved g^{-1} soil hr^{-1}. Treatment T_5 (20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) (7.64 µg CO_2 evolved g^{-1} soil hr^{-1}) registered the highest mean which was on par with T_2 (7.31 µg CO_2 evolved g^{-1} soil hr^{-1}) and T_7 (7.09 µg CO_2 evolved g^{-1} soil hr^{-1}). The lowest value was recorded by T_8 (40 kg N ha^{-1} as cattle manure) (5.42 µg CO_2 evolved g^{-1}soil hr^{-1}) which was significantly inferior to all other treatments.

4.1.5 Microbial Biomass Carbon

The treatments imposed significant difference with respect to microbial biomass carbon (Table 4). The mean values ranged from 217.97 µg g^{-1} soil for T_8 to 499.95 µg g^{-1} soil for T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}). T_7 was statistically on par with T_6 (466.835 µg g^{-1} soil). The least microbial biomass content was for T_8 (NPK @ 40:20:20 kg ha^{-1}).

4.1.6 Carbon Mineralisation Potential

The data summarized in Table 4 revealed significant influence of the treatments on carbon mineralisation potential of the soils which was estimated as their organic carbon levels. The mean values ranged from 0.82 to 1.75 per cent. The highest value of carbon mineralisation potential was noticed for the treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) (1.75 per cent) which was statistically on par with T_6 (1.36 per cent). The lowest value 0.82 per cent was noticed with the treatment T_8 (NPK @ 40:20:20 kg ha^{-1}) which was on par with treatments T_2 (1.18 per cent), T_3 (1.07 per cent), T_4 (0.93 per cent) and T_5 (0.97 per cent).

Table 4. Effect of treatments on microbial biomass carbon, C mineralisation potential, N mineralisation potential and hot water extractable soil carbohydrates (PMT- Tall)

Treatments	MBC ($\mu g\ g^{-1}$ soil)	C Mineralisation (%)	N Mineralisation ($kg\ ha^{-1}$)	HWC ($mg\ kg^{-1}$ soil)
T_1	319.39	1.33	250.63	3035.68
T_2	338.32	1.18	278.15	3909.38
T_3	244.67	1.07	338.72	2787.53
T_4	255.38	0.93	313.35	2905.48
T_5	380.96	0.97	301.59	3608.55
T_6	466.84	1.36	351.74	4782.55
T_7	499.95	1.75	439.19	4940.90
T_8	217.97	0.82	413.69	2483.25
CD (0.05)	45.84	0.39	22.09	369.91

T_1 : 40 kg N ha^{-1} as cattle manure

T_2 : 40 kg N ha^{-1} as green leaf

T_3 : 20 kg N ha^{-1} as cattle manure + 20 kg N ha^{-1} as green leaf

T_4 : 40 kg N ha^{-1} as ammonium sulphate

T_5 : 20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_6 : 20 kg N ha^{-1} as green leaf+ NPK @ 20:20:20 kg ha^{-1}

T_7 : 10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_8 : NPK @ 40:20:20 kg ha^{-1}

4.1.7 Nitrogen Mineralisation Potential

It is observed from table 4 that the mean values of nitrogen mineralisation potential ranged from 250.63 to 439.19 kg ha^{-1}. Treatment T_7 (10 kg N ha^{-1} as green leaf +10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) is significantly superior to all other treatments. The lowest value of nitrogen mineralisation potential, 250.63 kg ha^{-1} was recorded by T_1 (40 kg N ha^{-1} as cattle manure) which was significantly inferior to all other treatments.

4.1.8 Hot Water Extractable Soil Carbohydrates

Analysis of data presented in Table 4 revealed that the hot water extractable carbohydrates in soil was significantly influenced by different treatments. The mean values ranged from 2483.25 to 4940.90 mg kg^{-1}. Treatment T_7 (10 kg N ha^{-1} as green leaf +10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) which registered the maximum value of 4940.90 mg kg^{-1} was on par with treatment T_6 with mean value of 4782.55 mg kg^{-1}. The lowest value of 2483.25 mg kg^{-1} was recorded by the treatment T_8 (NPK @ 40:20:20 kg ha^{-1}) to which T_3 was on par recording a value of 2787.53 mg kg^{-1}.

4.1.9 PLANT CHARACTERS

4.1.9.1 Biometric Characters

4.1.9.1.1 Plant Height

The plant height varied significantly with respect to treatments as can be observed from Table 5. The mean values ranged from 134.08 to 147.88 cm. Treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) registered the maximum value of 147.88 cm and was on par with the treatments T_5 (144.6 cm) and T_8 (141.7 cm). The lowest value for plant height (134.08 cm) was noticed in T_4 (40 kg N ha^{-1} as ammonium sulphate).

4.1.9.1.2 Number of Tillers per Plant

It can be observed from table 5 that there was significant difference in number of tillers $plant^{-1}$ due to treatments. Average values of number of tillers ranged from 7.58 to 10.05. The highest number of tillers was noticed for the treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @

Table 5. Effect of treatments on plant characters and yield (PMT- Tall)

Treatments	Plant characters			Yield (kg ha^{-1})	
	Plant height (cm)	No. of tillers plant^{-1}	No. of panicles plant^{-1}	Grain	Straw
T_1	139.18	8.50	8.33	3421.00	4217.00
T_2	138.60	7.65	7.65	2927.50	3595.00
T_3	137.90	8.13	7.85	3096.25	4192.00
T_4	134.08	7.58	7.18	2655.00	3376.25
T_5	144.60	9.43	8.83	3414.75	4256.50
T_6	136.68	7.85	7.45	2818.00	3734.00
T_7	147.88	10.05	9.93	3563.25	4694.00
T_8	141.70	8.30	7.93	3123.00	3826.00
CD (0.05)	7.37	1.38	1.52	21.64	16.14

T_1 : 40 kg N ha^{-1} as cattle manure

T_2 : 40 kg N ha^{-1} as green leaf

T_3 : 20 kg N ha^{-1} as cattle manure + 20 kg N ha^{-1} as green leaf

T_4 : 40 kg N ha^{-1} as ammonium sulphate

T_5 : 20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_6 : 20 kg N ha^{-1} as green leaf+ NPK @ 20:20:20 kg ha^{-1}

T_7 : 10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_8 : NPK @ 40:20:20 kg ha^{-1}

20:20:20 kg ha^{-1}) with a mean value of 10.05 which are statistically on par with T_5 (9.43). The lowest value of 7.58 was recorded for the treatment T_4 (40 kg N ha^{-1} as ammonium sulphate).

4.1.9.1.3 Number of Panicles per Plant

Effects of treatments on number of panicles $plant^{-1}$ are presented in table 5. Average values of number of panicles ranged from 7.18 to 9.93. Treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) registered the maximum value of 9.93. It was statistically on par with the treatments T_5 with mean value of 8.83 and T_1 (8.50). The lowest value for number of panicle was 7.18 noticed in T_4 (40 kg N ha^{-1} as ammonium sulphate).

4.1.9.2 Yield

4.1.9.2.1 Grain Yield

Statistical analysis of data revealed (table 5.) that the treatments significantly influenced the grain yield of Rabi crop (2012-13) of (PMT- Tall). Yield values ranged from 2655.00 to 3563.25 kg ha^{-1}. The highest mean value of 3563.25 kg ha^{-1} was recorded by the treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) which was significantly superior to all other treatments. The lowest value of grain yield (2655.00 kg ha^{-1}) was noticed in treatment T_4 (40 kg N ha^{-1} as ammonium sulphate) which was significantly inferior to all other treatments.

4.1.9.2.2 Straw Yield

Application of various treatments significantly influenced straw yield obtained for Rabi crop (2012-13) of (PMT- Tall) indicated in (Table 5). Straw yield values ranged from 3376.25 to 4694.00 kg ha^{-1}. The highest mean value of 4694 kg ha^{-1} was recorded by the treatment T_7 (10 kg N ha^{-1} as green leaf +10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) which was significantly superior to all other treatments. The treatment T_4 (40 kg N ha^{-1} as ammonium sulphate) recorded the lowest value for the straw yield which was significantly lower than other treatments.

Table 6. Effect of treatments on some soil characteristics (Kharif 2012-13) (PMT- Tall)

Treatments	pH	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	5.76	39.96	104.74
T_2	5.88	34.52	113.03
T_3	5.77	37.33	112.02
T_4	5.76	27.36	108.99
T_5	5.95	47.13	121.58
T_6	5.85	28.25	119.20
T_7	5.83	55.37	151.01
T_8	5.51	36.26	132.05
CD (0.05)	0.187	12.192	27.667

T_1 : 40 kg N ha^{-1} as cattle manure

T_2 : 40 kg N ha^{-1} as green leaf

T_3 : 20 kg N ha^{-1} as cattle manure + 20 kg N ha^{-1} as green leaf

T_4 : 40 kg N ha^{-1} as ammonium sulphate

T_5 : 20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_6 : 20 kg N ha^{-1} as green leaf+ NPK @ 20:20:20 kg ha^{-1}

T_7 : 10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}

T_8 : NPK @ 40:20:20 kg ha^{-1}

4.1.10 Soil Characteristics

The following soil characters relate to Kharif crop (2012-13) of (PMT- Tall) and were acquired from the basic records maintained at RARS, Pattambi.

4.1.10.1 pH

Imposition of treatments had a significant effect on the pH of the postharvest soil of (PMT- Tall) (Table 6). The mean values ranged from 5.51 to 5.95. Treatment T_5 (20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) reported the highest mean value of 5.95 which was found to be on par with T_2 (5.88), T_6 (5.85), T_7 (5.83) and T_3 (5.77). The lowest mean value was registered by the treatment T_8 (5.51) with the application of NPK @ 40:20:20 kg ha^{-1}.

4.1.10.2 Available Phosphorus

It can be observed from table 6 that the mean values of available P ranged from 27.36 to 55.37 kg ha^{-1}. Treatment T_7 (10 kg N ha^{-1} as green leaf +10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest mean value of 55.37 kg ha^{-1} and was found to be on par with treatment T_5 (47.13 kg ha^{-1}). The lowest value of available P, 27.36 kg ha^{-1} was recorded by T_4 (40 kg N ha^{-1} as ammonium sulphate)

4.1.10.3 Available Potassium

Various treatments significantly influenced the available K content of soil (Table 6). The mean values ranged from 104.74 to 151.01 kg ha^{-1}. The treatment T_7 (10 kg N ha^{-1} as green leaf +10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) registered the highest mean (151.01 kg ha^{-1}). It was on par with T_8 (132.05 kg ha^{-1}). The lowest value of 104.74 kg ha^{-1} was recorded by T_1 (40 kg N ha^{-1} as cattle manure).

4.2. EXPERIMENT NO.2: PERMANENT MANURIAL TRIAL (DWARF INDICA)

4.2.1 Soil Macrofauna

4.2.1.1 Earthworms

As in the case of (PMT- Dwarf) earthworm population could not be recorded for this experiment also due to their absolute absence in the top soil in all the plots.

4.2.1.1 Arthropods

The data summarized in Table 7 illustrate the significant effects of treatments on soil arthropod count. The mean values ranged from 32.50 no. kg^{-1} soil to 60.75 no. kg^{-1} soil. The treatment T_3 (45 kg N ha^{-1} as cattle manure + 45 kg N ha^{-1} as green manure) recorded highest value of 60.75 no. kg^{-1} soil and was statistically on par with T_5 (48.50 no. kg^{-1} soil) and T_7 (49.50 no. kg^{-1} soil). Treatment T_8 (NPK @ 90:45:45 kg ha^{-1}) registered the lowest mean (32.50 no.kg^{-1} soil).

4.2.2 Soil Microflora

4.2.2.1 Bacteria

Various treatments significantly influenced the bacterial count of soil (Table 7.). The mean values ranged from 32.75 x 10^6 cfu g^{-1} soil to 86.50 x 10^6 cfu g^{-1} soil. Treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) registered the highest mean value of 86.50 x 10^6 cfu g^{-1} soil which was on par with T_2 (90 kg N ha^{-1} as green leaf) (83.25 x 10^6 cfu g^{-1} soil). The lowest value was recorded by T_8 (NPK @ 90:45:45kg ha^{-1}) (32.75 x 10^6 cfu g^{-1} soil) which was par with T_1 (41.50 x 10^6 cfu g^{-1} soil), T_3 (46.50 x 10^6 cfu g^{-1} soil) T_4 (36.00 x 10^6 cfu g^{-1} soil) and T_6 (47.00 x 10^6 cfu g^{-1} soil).

4.2.2.2 Actinomycetes

The different treatments significantly influenced the actinomycetes count in soil (Table 7.). The actinomycetes population ranged from 7.25 x 10^3 cfu g^{-1} soil to 16.00 x 10^3 cfu g^{-1}soil. The highest mean value of 16.00 x 10^3 cfu g^{-1} soil was recorded by the treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as

Table 7. Effect of treatments on soil macro fauna and micro flora (PMT- Dwarf)

Treatments	Soil macro fauna	Soil micro flora	
	Arthropods count (no. kg^{-1} soil)	Bacteria (x 10^6 cfu g^{-1} soil)	Actinomycetes (x 10^3 cfu g^{-1} soil)
T_1	45.75	41.50	7.75
T_2	37.50	83.25	13.00
T_3	60.75	46.50	11.00
T_4	33.00	36.00	7.75
T_5	48.50	54.50	10.50
T_6	42.25	47.00	12.25
T_7	49.50	86.50	16.00
T_8	32.50	32.75	7.25
CD (0.05)	12.76	15.21	3.79

T_1 : 90 kg N ha^{-1} as cattle manure

T_2 : 90 kg N ha^{-1} as green leaf

T_3 : 45 kg N ha^{-1} as cattle manure + 45 kg N ha^{-1} as green manure

T_4 : 90 kg N ha^{-1} as ammonium sulphate

T_5 : 45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_6 : 45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}

T_7 : 22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_8 : NPK @ 90:45:45kg ha^{-1}

Table 8. Effect of treatments on soil micro flora (PMT- Dwarf)

Treatments	Soil micro flora			
	Fungi (x 10^4 cfu g^{-1} soil)	*Azospirillum* (x 10^4 cfu g^{-1} soil)	*Azotobacter* (x 10^3 cfu g^{-1} soil)	P solubilizers (x 10^4 cfu g^{-1} soil)
T_1	36.25	30.50	35.25	3.00
T_2	28.00	36.50	29.00	1.75
T_3	28.75	38.50	23.25	1.50
T_4	17.75	30.75	17.50	2.25
T_5	41.00	51.00	24.25	3.75
T_6	46.25	52.25	25.25	3.00
T_7	43.50	45.75	38.75	3.25
T_8	24.00	36.00	19.25	1.50
CD (0.05)	7.57	8.03	8.43	1.26

T_1 : 90 kg N ha^{-1} as cattle manure

T_2 90 kg N ha^{-1} as green leaf

T_3 : 45 kg N ha^{-1} as cattle manure + 45 kg N ha^{-1} as green manure

T_4 : 90 kg N ha^{-1} as ammonium sulphate

T_5 : 45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_6 : 45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}

T_7 : 22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_8 : NPK @ 90:45:45kg ha^{-1}

cattle manure + NPK @ 45:45:45 kg ha^{-1}) which was statistically on par with T_2 (90 kg N ha^{-1} as green leaf) (13.00 x 10^3 cfu g^{-1} soil). The lowest actinomycetes count was recorded for T_8 (NPK @ 90:45:45 kg ha^{-1}) with mean value of (7.25 x 10^3 cfu g^{-1} soil).

4.2.2.3 Fungi

It can be seen from Table 8 that the fungal count ranged from 17.75 to 46.25 x 10^4 cfu g^{-1} soil. Treatment T_6 (45 kg N ha^{-1} as green manure + NPK @ 45:45:45 kg ha^{-1}) recorded the highest mean value of 46.25 x 10^4 cfu g^{-1} soil and was found to be on par with treatment T_5 (41.00 x 10^4 cfu g^{-1} soil) and T_7 (43.50 x 10^4 cfu g^{-1} soil). T_4 (40 kg N ha^{-1} as ammonium sulphate) registered the lowest value of 17.75 x 10^4 cfu g^{-1} soil.

4.2.2.4 Azospirillum

The different treatments significantly influenced the *Azospirillum* count in soil (Table 8.). The mean values ranged from 30.50 for treatment T_1 to 52.25 x 10^4 cfu g^{-1} soil for the treatment T_6 (45 kg N ha^{-1} as green manure + NPK @ 45:45:45 kg ha^{-1}). T_6 was found to be on par with treatment T_5 (51.00 x 10^4 cfu g^{-1} soil) and T_7 (45.75 x 10^4 cfu g^{-1} soil). Treatment T_1 (90 kg N ha^{-1} as cattle manure) registered the lowest mean *Azospirillum* count of 30.50 x 10^4 cfu g^{-1} soil.

4.2.2.5 Azotobacter

Data revealed that there was significant difference in *Azotobacter* count (Table 8.). The mean values ranged from 17.50 to 38.75 x 10^3 cfu g^{-1} soil. Treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) recorded the highest value (38.75 x 10^3 cfu g^{-1} soil) which was on par with T_1 (90 kg N ha^{-1} as cattle manure) (35.25 x 10^3 cfu g^{-1}soil). Treatment T_4 (90 kg N ha^{-1} as ammonium sulphate) registered the least value 17.50 x 10^3 cfu g^{-1} soil. ***4.2.2.6 P-Solubilizers***

It can be observed from Table 8 that the mean values of phosphorus solubilizers ranged from 1.50 to 3.75 x 10^4 cfu g^{-1} soil. Treatment T_5 (45 kg N ha^{-1}

Table 9. Effect of treatments on soil enzymes and soil respiration (PMT- Dwarf)

Treatments	Soil enzymes			Soil respiration (mg CO_2 100 g^{-1} soil d^{-1})
	Urease (µg urea g^{-1} soil hr^{-1})	Phosphatase µg p-nitrophenol g^{-1}soil hr^{-1})	Dehydrogenase (µg TPF g^{-1}soil 24 hr^{1})	
T_1	142.23	26.66	247.67	7.46
T_2	195.47	25.91	218.79	7.20
T_3	248.94	35.01	243.19	7.39
T_4	281.98	29.43	326.85	7.34
T_5	356.65	19.55	366.35	7.43
T_6	337.59	32.39	390.52	7.94
T_7	406.24	36.38	496.99	7.71
T_8	228.22	39.15	202.55	6.83
CD (0.05)	7.19	5.07	39.66	0.44

T_1 : 90 kg N ha^{-1} as cattle manure

T_2 : 90 kg N ha^{-1} as green leaf

T_3 : 45 kg N ha^{-1} as cattle manure + 45 kg N ha^{-1} as green manure

T_4 : 90 kg N ha^{-1} as ammonium sulphate

T_5 : 45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_6 : 45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}

T_7 : 22.5 kg N ha^{-1} as green leaf + 22.5 Kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_8 : NPK @ 90:45:45kg ha^{-1}

as cattle manure + NPK @ 45:45:45 kg ha^{-1}) had the highest mean value of 3.75 x 10^4 cfu g^{-1} soil and was found to be on par with treatment T_1 (3.00 x 10^4 cfu g^{-1} soil), T_6 (3.00 x 10^4 cfu g^{-1} soil) and T_7 (3.25 x 10^4 cfu g^{-1} soil). The lowest phosphorus solubilizers count was recorded for T_8 (NPK @ 90:45:45 kg ha^{-1}) with mean value of (1.50 x 10^3 cfu g^{-1} soil) which was on par with T_2 (1.75 x 10^3 cfu g^{-1} soil), T_3 (1.50 x 10^3 cfu g^{-1} soil) and T_4 (2.25 x 10^3 cfu g^{-1} soil).

4.2.3 Soil Enzymes

4.2.3.1 Urease

It can be observed from the Table 9 that the treatments imposed significant effect with respect to urease activity. The mean values of urease activity ranged from 142.23 to 406.23 µg urea hydrolysed g^{-1} soil hr^{-1}. The highest value (406.24 µg urea hydrolysed g^{-1} soil hr^{-1}) was recorded for the treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) which was found to be significantly superior to other treatments. The treatment T_1 (90 kg N ha^{-1} as cattle manure) recorded the lowest value for the urease activity (142.23 µg urea hydrolysed g^{-1} soil hr^{-1}) which was significantly lower than other treatments.

4.2.3.2 Phosphatase

Data reveal that there was significant difference in phosphatase activity (Table 9) and the mean values of the phosphatase activity ranged from 19.55 to 39.15 µg of p- nitrophenol released g^{-1} soil hr^{-1}. The highest value of phosphatase activity was noticed for the treatment T_8 (NPK @ 90:45:45kg ha^{-1}) (39.15 µg of p- nitrophenol released g^{-1} soil hr^{-1}) which was statistically on par with T_3 (35.01 µg of p- nitrophenol released g^{-1} soil hr^{-1}) and T_7 (36.38 µg of p- nitrophenol released g^{-1} soil hr^{-1}). The lowest value of 19.55 µg of p- nitrophenol released g^{-1} soil hr^{-1} was recorded for the treatment T_5 (45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}). This was significantly lower than other treatments.

4.2.3.3 Dehydrogenase

Statistical analysis of data on dehydrogenase activity indicated significant effect due to long term treatments (Table 9). The mean values ranged from 202.55 to 496.99 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}. The highest mean value was observed for the treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) (496.99 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}) which was found to be significantly superior to all other treatments. The treatment T_8 (NPK @ 90:45:45 kg ha^{-1}) had the lowest value for the dehydrogenase activity (202.55 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}) which was on par with T_2 (218.79 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}).

4.2.4 Soil Respiratory Activity

Application of various treatments significantly influenced soil respiratory activity (Table 9). The mean values ranged from 6.83 to 7.94 µg CO_2 evolved g^{-1} soil hr^{-1}. Treatment T_6 (45 kg N ha^{-1} as green manure + NPK @ 45:45:45 kg ha^{-1}) registered the highest mean which was on par with T_7 (7.71 µg CO_2 evolved g^{-1} soil hr^{-1}). The lowest value was recorded by T_8 (6.83 µg CO_2 evolved g^{-1} soil hr^{-1}) with application of NPK @ 90:45:45 kg ha^{-1} which was on par with T_2 (90 kg N ha^{-1} as green leaf).

4.2.5 Microbial Biomass Carbon

The treatments imposed significant difference with respect to microbial biomass carbon (Table 10). The mean values ranged between 267.67 and 569.43 µg g^{-1} soil. The highest value of microbial biomass carbon was noticed for the treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) (569.43 µg g^{-1} soil) which was found to be significantly superior to all other treatments. The least significant treatment was for T_8 (NPK @ 90:45:45 kg ha^{-1}) with mean value of 267.67 µg g^{-1} soil. This was significantly lower than other treatments.

Table 10. Effect of treatments on MBC, C mineralisation potential, N mineralisation potential and hot water extractable soil carbohydrates (PMT- Dwarf)

Treatments	MBC ($\mu g\ g^{-1}$ soil)	C Mineralisation (%)	N Mineralisation ($kg\ ha^{-1}$)	HWC ($mg\ kg^{-1}$ soil)
T_1	390.62	1.96	318.23	4113.26
T_2	400.56	1.72	314.98	4617.42
T_3	383.08	1.82	394.63	3649.58
T_4	306.98	1.54	311.80	3167.59
T_5	430.78	1.67	289.28	4867.03
T_6	506.41	1.74	324.63	4945.17
T_7	569.43	1.63	371.43	5158.11
T_8	267.67	1.45	298.98	2119.84
CD (0.05)	9.88	0.23	67.16	88.46

T_1 : 90 kg N ha^{-1} as cattle manure

T_2 : 90 kg N ha^{-1} as green leaf

T_3 : 45 kg N ha^{-1} as cattle manure + 45 kg N ha^{-1} as green manure

T_4 : 90 kg N ha^{-1} as ammonium sulphate

T_5 : 45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_6 : 45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}

T_7 : 22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_8 : NPK @ 90:45:45kg ha^{-1}

4.2.6 Carbon Mineralisation Potential

The data summarized in Table 10 reveal the significant influence of treatment on carbon mineralisation potential. The highest value of carbon mineralisation potential was noticed for the treatment T_1 (90 kg N ha^{-1} as cattle manure) (1.96 per cent) which was statistically on par with T_3 (1.82 per cent) and T_6 (1.74 per cent). The lowest value of 1.45 per cent was noticed for the treatment T_8 (NPK @ 90:45:45 kg ha^{-1}) which was on par with the treatment T_4 (1.54 per cent), T_5 (1.67 per cent) and T_7 (1.63 per cent)

4.2.7 Nitrogen Mineralisation Potential

It can be observed from Table 10 that the mean values in the case of nitrogen mineralisation potential ranged from 289.28 to 394.63 kg ha^{-1}. Treatment T_3 (45 kg N ha^{-1} as cattle manure + 45 kg N ha^{-1} as green manure) recorded the highest mean value of nitrogen mineralisation potential i.e. 394.63 kg ha^{-1} and was found to be on par with treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) (371.43 kg ha^{-1}). The lowest value of nitrogen mineralisation potential, 289.278 kg ha^{-1} was recorded by T_5 (45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}).

4.2.8 Hot Water Extractable Soil Carbohydrates

Analysis of data presented in Table 10 revealed that hot water extractable soil carbohydrates were significantly influenced by different treatments in (PMT- Dwarf) field. Mean values of hot water extractable soil carbohydrates ranged from 2119.84 to 5158.11 mg kg^{-1} soil. Treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) registered the maximum value of 5158.11 mg kg^{-1} soil which was found to be significantly superior to other treatments. The lowest value of 2119.84 mg kg^{-1} soil was recorded by the treatment T_8 (NPK @ 90:45:45 kg ha^{-1}).

4.2.9 PLANT CHARACTERS

4.2.9.1 Biometric Characters

Table 11. Effect of treatments on plant characters and yield (PMT- Dwarf)

Treatments	Plant characters			Yield (kg ha^{-1})	
	Plant height (cm)	No. of tillers plant^{-1}	No. of panicles plant^{-1}	Grain	Straw
T_1	104.35	7.50	7.35	3411.75	4115.12
T_2	98.28	6.95	6.68	2809.50	3360.35
T_3	99.15	7.05	6.70	2989.50	3592.65
T_4	98.85	7.00	6.18	2673.00	3593.68
T_5	105.25	7.70	7.25	3369.00	4122.84
T_6	97.05	6.35	6.25	2731.00	3230.13
T_7	109.40	8.63	8.33	3574.00	3238.22
T_8	104.05	7.15	6.90	3117.00	3927.47
CD (0.05)	5.47	1.26	1.16	58.27	22.01

T_1 : 90 kg N ha^{-1} as cattle manure

T_2 : 90 kg N ha^{-1} as green leaf

T_3 : 45 kg N ha^{-1} as cattle manure + 45 kg N ha^{-1} as green manure

T_4 : 90 kg N ha^{-1} as ammonium sulphate

T_5 : 45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_6 : 45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}

T_7 : 22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_8 : NPK @ 90:45:45kg ha^{-1}

4.2.9.1.1 Plant Height

The plant height varied significantly with respect to treatments as can be observed from Table 11. The mean values ranged from 97.05 to 109.40 cm. Treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) registered the maximum value of 109.40 cm and it was on par with the treatments T_1 (104.35 cm), T_5 (105.25 cm) and T_8 (104.05 cm). The lowest value for plant height was 97.05 cm noticed in T_6 (45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}).

4.2.9.1.2 Number of Tillers per Plant

It is observed from table 11 that there was significant difference in number of tillers $plant^{-1}$ due to treatments. Average values of number of tillers ranged from 6.35 to 8.63. The highest number of tillers was noticed for the treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) with a maximum value of 8.63 which was statistically on par with T_1 (7.50) and T_5 (7.70). The lowest value of 6.35 was recorded by the treatment T_6 (45 kg N ha^{-1} as green manure + NPK @ 45:45:45 kg ha^{-1}).

4.2.9.1.3 Number of Panicles per Plant

Effect of treatments on number of panicles $plant^{-1}$ is given in Table 11. Average values of number of panicles ranged from 6.18 to 8.33. Treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) registered the maximum value of 8.33 and it was statistically on par with the treatments T_5 with mean value of 7.25 and T_1 (7.35). The lowest value for number of panicles was 6.18 noticed in T_4 (90 kg N ha^{-1} as ammonium sulphate).

4.2.9.2 Yield

4.2.9.2.1 Grain Yield

Statistical analysis of data reveals that treatments significantly influenced the grain yield (Table 11) in PMT conducted with Dwarf indica rice variety. Yield values ranged from 2673.00 to 3574.00 kg ha^{-1}. The highest mean value of 3574.00 kg ha^{-1} was recorded by the treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) which was

Table 12. Effect of treatments on soil characteristics (PMT- Dwarf)

Treatments	pH	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	5.64	37.01	111.04
T_2	5.89	21.49	123.89
T_3	5.68	44.48	132.25
T_4	5.64	22.83	77.31
T_5	5.47	46.41	98.58
T_6	5.58	41.55	143.50
T_7	5.49	61.13	112.41
T_8	5.52	42.77	104.52
CD (0.05)	0.21	21.96	36.69

T_1 : 90 kg N ha^{-1} as cattle manure

T_2 : 90 kg N ha^{-1} as green leaf

T_3 : 45 kg N ha^{-1} as cattle manure + 45 kg N ha^{-1} as green manure

T_4 : 90 kg N ha^{-1} as ammonium sulphate

T_5 : 45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_6 : 45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}

T_7 : 22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}

T_8 : NPK @ 90:45:45kg ha^{-1}

significantly superior to all other treatments. The lowest value of grain yield (2673.00 kg ha^{-1}) was registered for treatment T_4 (90 kg N ha^{-1} as ammonium sulphate) which was on par with treatment T_6 (45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}).

4.2.9.2.2 Straw Yield

Application of various treatments significantly influenced straw yield (Table 11). Straw yield values ranged from 3230.00 to 4122.00 kg ha^{-1}. The highest mean value of 4122.00 kg ha^{-1} was recorded by the treatment T_5 (45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) which was found to be on par with treatment T_1 (90 kg N ha^{-1} as cattle manure) (4115.00 kg ha^{-1}). The treatment T_6 (45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}) recorded the lowest mean value of (3230.00 kg ha^{-1}) for the straw yield which was on par with treatment T_7 (3238.00 kg ha^{-1}).

4.2.10 Soil Characteristics

4.2.10.1 pH

Imposition of treatments had a significant effect on the pH of the postharvest soil (Table12.). The mean values ranged from 5.47 to 5.89. Treatment T_2 (90 kg N ha^{-1} as green leaf) reported the highest mean value of 5.89, which was significantly superior to all other treatments. The lowest mean value was registered by the treatment T_5 (5.47) with the application of 45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}.

4.2.10.2 Available Phosphorus

It can be seen from table 12 that the mean values in the case of available P ranged from 21.49 to 61.13 kg ha^{-1}. Treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK 45:45:45 kg ha^{-1}) recorded the highest mean value of available P (61.13 kg ha^{-1}) and was found to be on par with treatment T_5 (46.405 kg ha^{-1}), T_3 (44.4825 kg ha^{-1}), T_8 (42.773 kg ha^{-1}) and T_6 (41.55 kg ha^{-1}). The lowest value of available P, 21.49 kg ha^{-1} was recorded by T_2 (90 kg N ha^{-1} as green leaf).

4.2.10.3. Available Potassium

Various treatments significantly influenced the available potassium content of soil (Table 12). The mean values ranged from 77.31 to 143.50 kg ha^{-1}. The treatment T_6 (45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}) registered the highest mean (143.50 kg ha^{-1}) which was on par with T_1 (111.04 kg ha^{-1}), T_2 (123.89 kg ha^{-1}), T_3 (132.25 kg ha^{-1}) and T_7 (112.41kg ha^{-1}). The lowest value of 77.31 kg ha^{-1} was recorded by T_4 (90 kg N ha^{-1} as ammonium sulphate).

4.3 EXPERIMENT NO. 3: AICRP ON LONG TERM FERTILIZER EXPERIMENTS

4.3.1 Soil Macrofauna

4.3.1.1 Earthworms

The data included in Table 13 show the effect of different treatments on earthworm count in soil. The counts were significantly influenced by the treatments in long term experiment field. Mean values ranged between 3.75 and 16.25 no. m^{-2} soil. Treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) recorded the maximum earthworm count of 16.25 no. m^{-2} soil which was found to be significantly superior to other treatments. The treatment T_1 (50 per cent NPK as per KAU POP recommendation) recorded the lowest value for earthworm count (3.75).

4.3.1.2 Arthropods

The data summarized in Table 13 showed significant effect of long term treatments on soil arthropod count. The mean values ranged from 32.50 to 78.00 no. kg^{-1} soil. The treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) recorded the highest mean value of 78.00 nos. kg^{-1} soil which was statistically on par with T_{10} (100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)) with mean of 63.75 no. kg^{-1}soil. Treatment T_4 (100 percent NPK + lime @ 600 kg ha^{-1}) registered the lowest mean (32.50 no. kg^{-1} soil).

4.3.2 Soil Microflora

4.3.2.1 Bacteria

Various long term treatments significantly influenced the bacterial count in soil (Table 14). The mean values ranged from 24.00 to 61.50 x 10^6 cfu g^{-1} soil. Treatment T_8 (100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) registered the highest mean value (61.50 x 10^6 cfu g^{-1} soil) which was on par with T_{10} (100 percent NPK+ *in situ* growing of *Sesbania aculeata* (for Kharif crop only)) with mean of 52.25 x 10^6 cfu g^{-1} soil. The lowest value was recorded by T_{12} (Absolute control (No fertilizer)) (24.00 x10^6 cfu g^{-1} soil) which was on par

Table 13. Effect of treatments on soil macro fauna (LTFE)

Treatments	Soil macro fauna	
	Earth worm count (no. m^{-2})	Arthropods count (no. kg^{-1} soil)
T_1	3.75	55.00
T_2	5.75	34.25
T_3	5.75	47.50
T_4	6.00	32.50
T_5	5.00	44.00
T_6	7.75	49.50
T_7	4.75	46.75
T_8	16.25	78.00
T_9	12.00	49.00
T_{10}	11.25	63.75
T_{11}	11.75	43.50
T_{12}	7.00	40.50
CD (0.05)	4.03	21.06

T_1 : 50 percent NPK (as per KAU POP recommendation)

T_2 : 100 percent NPK

T_3 : 150 percent NPK

T_4 : 100 percent NPK + lime @ 600 kg ha^{-1}

T_5 : 100 percent NPK +$CuSO_4$ 5 kg ha^{-1} (if deficiency symptoms appear)

T_6 : 100 percent NP

T_7 : 100 percent N

T_8 : 100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_9 : 50 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_{10} : 100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)

T_{11} : 50 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)

T_{12} : Absolute control (No fertilizer)

Table 14. Effect of treatments on soil macro flora (LTFE)

Treatments	Soil micro flora					
	Bacteria (x 10^6 cfu g^{-1} soil)	Actinomycetes (x 10^3 cfu g^{-1} soil)	Fungi (x 10^4 cfu g^{-1} soil)	*Azospirillum* (x 10^4 cfu g^{-1} soil)	*Azotobacter* (x 10^3 cfu g^{-1} soil)	P solubilizers (x 10^4 cfu g^{-1} soil)
T_1	33.00	4.50	23.75	22.50	15.75	2.00
T_2	39.75	5.50	26.00	25.75	17.50	4.75
T_3	40.75	6.00	26.75	28.75	18.25	3.75
T_4	37.50	5.25	24.50	23.75	16.75	4.00
T_5	39.25	5.25	25.75	25.00	19.75	2.75
T_6	32.00	4.00	21.25	20.25	12.25	3.00
T_7	29.50	3.50	18.50	17.25	10.75	0.5
T_8	61.50	11.25	48.50	42.25	28.25	4.25
T_9	48.50	7.00	41.50	31.25	20.75	2.00
T_{10}	52.25	9.00	36.75	34.75	24.75	2.00
T_{11}	43.75	6.25	34.50	29.75	20.25	1.25
T_{12}	24.00	2.50	15.25	15.50	9.50	0.25
CD (0.05)	9.65	3.35	9.18	9.88	7.65	1.54

T_1 : 50 percent NPK (as per KAU POP recommendation)

T_2 : 100 percent NPK

T_3 : 150 percent NPK

T_4 : 100 percent NPK + lime @ 600 kg ha^{-1}

T_5 : 100 percent NPK +$CuSO_4$ 5 kg ha^{-1} (if deficiency symptoms appear)

T_6 : 100 percent NP

T_7 : 100 percent N

T_8 : 100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_9 : 50 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_{10} : 100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)

T_{11} : 50 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)

T_{12} : Absolute control (No fertilizer)

with T_1 (33.00 x10^6 cfu g^{-1} soil), T_6 (32.00 x 10^6 cfu g^{-1}soil) and T_7 (29.50 x 10^6 cfu g^{-1} soil).

4.3.2.2 Actinomycetes

From table 14 we can assess the treatment effect on actinomycetes population. The mean values ranged from 2.50 to 11.25 x 10^3 cfu g^{-1}soil. The highest mean value of (11.25 x 10^3 cfu g^{-1} soil) was recorded by the treatment T_8 (100 per cent NPK + FYM @ 5t ha^{-1} (to Kharif crop only)) which was statistically on par with T_{10} (9.00 x 10^3 cfu g^{-1} soil). The lowest actinomycetes count was recorded by T_{12} (Absolute control (No fertilizer)) with mean value of 2.50 x 10^3 cfu g^{-1} soil.

4.3.2.3 Fungi

It can be observed from table 14 that the mean values in the case of fungal count ranged from 15.25 to 48.50 x 10^4 cfu g^{-1} soil. Treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) recorded the highest mean value of 48.50 x 10^4 cfu g^{-1} soil and was found to be on par with treatment T_9 (50 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) (41.50 x 10^4 cfu g^{-1} soil). T_{12} (Absolute control (No fertilizer)) recorded the lowest value of 15.25 x 10^4 cfu g^{-1}soil.

4.3.2.4 Azospirillum

Various long term treatments significantly influenced the population of *Azospirillum* in soil (Table 14). The mean values of *Azospirillum* count ranged from 15.50 to 42.25 x 10^4 cfu g^{-1} soil. The treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) recorded the highest mean value of 42.25 x 10^4 cfu g^{-1} soil and was found to be on par with treatment T_{10} (34.75 x 10^4 cfu g^{-1} soil). Absolute control (T_{12}) registered the lowest mean *Azospirillum* count of 15.50 x 10^4 cfu g^{-1}soil.

4.3.2.5 Azotobacter

Data reveal that there was significant difference in population of *Azotobacter* in long term treated soil (Table 14). The mean values ranged from

Table 15. Effect of treatments on soil enzymes and soil respiration (LTFE)

Treatments	Soil enzymes			Soil respiration (mg CO_2 100 g^{-1}soil d^{-1})
	Urease (µg urea g^{-1} soil hr^{-1})	Phosphatase (µg p- nitrophenol g^{-1}soil hr^{-1})	Dehydrogenase (µg TPF g^{-1} soil 24 hr^{-1})	
T_1	165.75	18.08	160.73	5.99
T_2	192.50	19.11	106.93	5.91
T_3	202.75	19.22	106.82	5.74
T_4	180.25	21.49	207.35	6.07
T_5	163.00	20.40	150.98	6.17
T_6	180.75	27.96	121.23	6.05
T_7	214.25	19.68	164.79	5.86
T_8	239.00	39.15	394.41	7.03
T_9	216.50	28.13	313.67	6.85
T_{10}	223.50	29.90	368.25	6.62
T_{11}	205.00	27.89	257.39	6.67
T_{12}	141.50	17.63	188.28	3.63
CD (0.05)	9.09	2.87	7.38	0.62

T_1 : 50 percent NPK (as per KAU POP recommendation)

T_2 : 100 percent NPK

T_3 : 150 percent NPK

T_4 : 100 percent NPK + lime @ 600 kg ha^{-1}

T_5 : 100 percent NPK +CuSO4 5 kg ha^{-1} (if deficiency symptoms appear)

T_6 : 100 percent NP

T_7 : 100 percent N

T_8 : 100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_9 : 50 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_{10} : 100 percent NPK + in situ growing of *Sesbania aculeata* (for Kharif crop only)

T_{11} : 50 percent NPK + in situ growing of *Sesbania aculeata* (for Kharif crop only)

T_{12} : Absolute control (No fertilizer)

9.50 to 28.25 x 10^3 cfu g^{-1} soil. Treatment T_8 (100 per cent NPK + FYM @ 5t ha^{-1} (to Kharif crop only)) recorded the highest values of *Azotobacter* count (28.25 x 10^3 cfu g^{-1} soil) which was on par with T_9 (20.75 x 10^3 cfu g^{-1} soil) and T_{10} (24.75 x 10^3 cfu g^{-1} soil). Absolute control (T_{12}) registered the least value of 9.50 x 10^3 cfu g^{-1} soil.

4.3.2.6 P Solubilizers

It can be observed (Table 14) that the population phosphorus solubilizers count ranged from 0.25 to 4.75 x 10^4 cfu g^{-1}soil. Treatment T_2 (100 percent NPK) recorded the highest mean value of 4.75 x 10^4 cfu g^{-1}soil and was found to be on par with treatment T_3 (3.75 x 10^4 cfu g^{-1} soil), T_4 (4.00 x 10^4 cfu g^{-1} soil) and T_8 (4.25 x 10^4 cfu g^{-1}soil). The lowest phosphorus solubilizers count was recorded by T_{12} (Absolute control (No fertilizer)) with mean value of 0.25 x 10^3 cfu g^{-1} soil which was on par with T_7 (0.50 x 10^3 cfu g^{-1} soil) and T_{11} (1.25 x 10^3 cfu g^{-1} soil).

4.3.3 Soil Enzymes

4.3.3.1 Urease

It is observed from the table 15 that the treatments imposed significant effect with respect to urease activity. The mean values of urease activity ranged from 141.50 to 239.00 µg urea hydrolysed g^{-1} soil hr^{-1}. The highest value was recorded for the treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) (239.00 µg urea hydrolysed g^{-1} soil hr^{-1}) which was found to be significantly superior to all other treatments. The treatment T_{12} (Absolute control (No fertilizer)) recorded the lowest value for the urease activity (141.50 µg urea hydrolysed g^{-1} soil hr^{-1}) which was significantly lower than all other treatments.

4.3.3.2 Phosphatase

Data reveal that there was significant difference in phosphatase activity among the different treatments (Table 15). The mean values for phosphatase ranged from 17.63 to 38.54 µg of p- nitrophenol released g^{-1} soil hr^{-1}. Treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) was noticed to have the highest phosphatase activity (38.54 µg of p- nitrophenol released g^{-1} soil

hr^{-1}) which was significantly superior to all other treatments. The lowest value of 17.63 µg of p- nitrophenol released g^{-1} soil hr^{-1} was recorded by the treatment T_{12} (Absolute control (No fertilizer)).

4.3.3.3 Dehydrogenase

Statistical analysis of data on dehydrogenase activity indicated highly significant effect due to long term treatments (Table 15). The mean values ranged from 106.82 to 394.41 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}. The highest value was recorded for the treatment T_8 (394.41 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}) which was found to be significantly superior to other treatments. The treatment T_3 (150 percent NPK) recorded the lowest value for the dehydrogenase activity (106.82 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}) which was on par with T_2 (106.93 µg TPF hydrolysed g^{-1} soil 24 hr^{-1}).

4.3.4 Soil Respiratory Activity

Application of various treatments significantly influenced soil respiratory activity (Table 15). The mean values ranged from 3.63 to 7.03 µg CO_2 evolved g^{-1} soil hr^{-1}. Treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) registered the highest mean (7.03 µg CO_2 evolved g^{-1} soil hr^{-1}) which was on par with T_9 (6.85 µg CO_2 evolved g^{-1} soil hr^{-1}), T_{10} (6.62 µg CO_2 evolved g^{-1} soil hr^{-1}) and T_{11} (6.67 µg CO_2 evolved g^{-1} soil hr^{-1}). The lowest value was recorded by absolute control (T_{12}) (3.63 µg CO_2 evolved g^{-1} soil hr^{-1}) which was significantly inferior to all other treatments.

4.3.5 Microbial Biomass Carbon

The treatments imposed significant differences with respect to microbial biomass carbon (Table 16). The mean values of MBC ranged from 205.45 to 552.75 µg g^{-1} soil. The treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) was observed to possess the highest value of microbial biomass carbon (552.75 µg g^{-1} soil) which was significantly superior to all other treatments. The least significant treatment was T_{12} (Absolute control) with mean

Table 16. Effect of treatments on MBC, C mineralisation potential, N mineralisation potential and hot water extractable soil carbohydrates (LTFE)

Treatments	MBC ($\mu g\ g^{-1}$ soil)	C Mineralisation (%)	N Mineralisation ($kg\ ha^{-1}$)	HWC ($mg\ kg^{-1}$ soil)
T_1	242.61	1.58	192.73	2860.25
T_2	332.40	1.70	205.71	3051.75
T_3	223.36	1.79	214.21	3877.01
T_4	353.23	1.69	216.71	3071.67
T_5	317.73	1.69	199.66	3714.53
T_6	338.58	1.66	201.20	3644.80
T_7	244.06	1.51	208.74	3081.21
T_8	552.75	1.90	228.83	5917.08
T_9	515.43	1.83	222.25	5583.59
T_{10}	468.65	1.89	250.21	5014.13
T_{11}	420.45	1.74	234.71	4888.59
T_{12}	205.45	1.32	177.27	2132.43
CD (0.05)	33.31	0.05	12.21	315.04

T_1 : 50 percent NPK (as per KAU POP recommendation)

T_2 : 100 percent NPK

T_3 : 150 percent NPK

T_4 : 100 percent NPK + lime @ 600 $kg\ ha^{-1}$

T_5 : 100 percent NPK +CuSO4 5 $kg\ ha^{-1}$ (if deficiency symptoms appear)

T_6 : 100 percent NP

T_7 : 100 percent N

T_8 : 100 percent NPK + FYM @ 5 $t\ ha^{-1}$ (to Kharif crop only)

T_9 : 50 percent NPK + FYM @ 5 $t\ ha^{-1}$ (to Kharif crop only)

T_{10} : 100 percent NPK + in situ growing of *Sesbania aculeata* (for Kharif crop only)

T_{11} : 50 percent NPK + in situ growing of *Sesbania aculeata* (for Kharif crop only)

T_{12} : Absolute control (No fertilizer)

value of 205.45 µg g^{-1} soil. This was statistically on par with treatment T_3 (150 percent NPK) with mean value 223.36 µg g^{-1} soil.

4.3.6 Carbon Mineralisation Potential

The data summarized in Table 16 showed significant influence of treatments on carbon mineralisation potential. The highest value of carbon mineralisation potential was noticed for the treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) with 1.90 per cent which was statistically on par with T_{10} (100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)) (1.89 per cent). The lowest value of 1.32 per cent was noticed for the treatment absolute control (T_{12}) which was significantly inferior to all other treatments.

4.3.7 Nitrogen Mineralisation Potential

It can be observed from table 16 that the mean values in the case of nitrogen mineralisation potential ranged from 177.27 to 250.21 kg ha^{-1}. Treatment T_{10} (100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)) recorded the highest mean value of 250.21 kg ha^{-1} which was significantly superior to all other treatments. The lowest value of nitrogen mineralisation potential (177.27 kg ha^{-1}) was recorded by T_{12} (absolute control) which was significantly inferior to all other treatments.

4.3.8 Hot Water Extractable Soil Carbohydrates

Analysis of data (Table 16) revealed that hot water extractable soil carbohydrates were significantly influenced by different treatments in LTFE field. Mean values of hot water extractable soil carbohydrates ranged from 2132.43 to 5917.08 mg kg^{-1}. Treatment combination T_8 (100 per cent NPK + FYM @ 5t ha^{-1} (to Kharif crop only)) had the maximum value of 5917.08 mg kg^{-1}which was found to be significantly superior to all other treatments. The lowest value of 2132.43 mg kg^{-1} was recorded for absolute control (T_{12}) which was significantly lower than all other treatments.

Table 17. Effect of treatments on plant characters (LTFE)

Treatments	Plant characters			Yield (kg ha^{-1})	
	Plant height (cm)	No. of tillers plant^{-1}	No. of panicles plant^{-1}	Grain	Straw
T_1	95.93	8.31	8.12	2939.25	2807.41
T_2	102.48	8.63	8.45	3263.75	3062.01
T_3	102.15	8.88	8.83	3430.75	3302.27
T_4	97.05	8.63	8.23	3237.25	3189.79
T_5	98.25	8.35	8.18	3121.00	3021.73
T_6	98.53	8.29	8.07	2920.75	2919.91
T_7	93.23	8.28	7.98	2714.75	2619.27
T_8	100.10	11.23	11.08	3922.00	3839.85
T_9	98.88	9.68	9.38	3553.75	3475.98
T_{10}	107.63	11.30	10.43	3827.50	3870.71
T_{11}	96.15	8.85	8.75	3440.75	3089.62
T_{12}	88.67	7.98	7.80	2676.00	2528.36
CD (0.05)	7.37	1.59	1.75	69.07	159.87

T_1 : 50 percent NPK (as per KAU POP recommendation)

T_2 : 100 percent NPK

T_3 : 150 percent NPK

T_4 : 100 percent NPK + lime @ 600 kg ha^{-1}

T_5 : 100 percent NPK +CuSO4 5 kg ha^{-1} (if deficiency symptoms appear)

T_6 : 100 percent NP

T_7 : 100 percent N

T_8 : 100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_9 : 50 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_{10} : 100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)

T_{11} : 50 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)

T_{12} : Absolute control (No fertilizer)

4.3.9 PLANT CHARACTERS$

4.3.9.1 Biometric Characters

4.3.9.1.1 Plant Height

The plant height varied significantly with respect to treatments as can be observed from table 17. The mean values ranged from 88.67 to 107.63 cm. Treatment T_{10} (100 per cent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)) was recored the maximum value of 107.63 cm and was on par with the treatments T_2 (102.48 cm) and T_3 (102.15 cm). The lowest value for plant height was (88.67 cm) noticed in T_{12} (Absolute control) and was found to be on par with T_1 (95.93 cm) and T_7 (93.23 cm).

4.3.9.1.2 Number of Tillers per Plant

It can be observed from table 17 that there were significant differences in number of tillers plant^{-1} due to treatments. Average values of number of tillers ranged from 7.98 to 11.30. The highest number of tillers was noticed for the treatment T_{10} (100 per cent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)) with a maximum value of 11.30 which was statistically on par with T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) (11.23). The lowest value of 7.98 was recorded by the treatment T_{12} (Absolute control).

4.3.9.1.3 Number of Panicle per Plant

The data depicting the effect of treatments on number of panicles plant^{-1} are given in Table 17. Average values of number of panicles ranged from 7.80 to 11.08. Treatment T_8 (100 per cent NPK + FYM @ 5t ha^{-1} (to Kharif crop only)) registered the maximum value of 11.08 and it was statistically on par with the treatment T_{10} (100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)) with mean value of 10.43. The lowest value for number of panicles 7.80 was noticed in T_{12} (Absolute control).

4.3.9.2 Yield

4.3.9.2.1 Grain Yield

Statistical analysis of data revealed that the treatments significantly influenced the grain yield in LTFE. Yield ranged from 2676.00 to 3922.00 kg ha^{-1}. The highest mean value of 3922.00 kg ha^{-1} was recorded by the treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) which was significantly superior to all other treatments followed by treatment T_{10} (100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)) with mean value 3827.50 kg ha^{-1} and T_9 with 3553.75 kg ha^{-1}. The lowest value of grain yield 2676.00 kg ha^{-1} was noticed in treatment T_{12} (Absolute control) which was on par with treatment T_7 (100 percent N) with mean value of 2714.75 kg ha^{-1}.

4.3.9.2.2 Straw Yield

Application of various treatments significantly influenced straw yield in LTFE. Straw yield values ranged from 2528.36 to 3870.71 kg ha^{-1}. The highest mean value of 3870.71 kg ha^{-1} was observed by the treatment T_{10} (100 per cent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)) which was found to be on par with treatment T_8 (100 per cent NPK + FYM @ 5t ha^{-1} (to Kharif crop only)) (3839.85 kg ha^{-1}). The treatment T_{12} (Absolute control) recorded the lowest mean value of 2528.36 kg ha^{-1} for straw yield which was on par with treatment T_7 (100 percent N) with mean value of 2619.27 kg ha^{-1}.

4.3.10 Soil Characters

4.3.10.1 pH

Imposition of treatments had a significant effect on the pH of the postharvest soil of LTFE (Table 18). The mean values ranged from 5.15 to 5.75. Treatment T_4 (100 per cent NPK + lime @ 600 kg ha^{-1}) reported the highest mean value of 5.75, which was significantly superior to all other treatments. The lowest mean value was registered by the treatment T_3 (5.15) with the application of 150 per cent NPK.

Table 18. Effect of treatments on soil characters (LTFE)

Treatments	p^H	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	5.35	17.42	75.46
T_2	5.22	19.97	81.72
T_3	5.15	20.35	93.11
T_4	5.75	20.04	81.44
T_5	5.35	19.87	80.83
T_6	5.16	18.32	68.86
T_7	5.40	13.42	54.61
T_8	5.32	21.29	97.79
T_9	5.16	18.24	82.43
T_{10}	5.45	21.21	93.01
T_{11}	5.21	18.78	85.53
T_{12}	5.27	12.54	64.40
$CD_{(0.05)}$	0.25	0.79	6.27

T_1 : 50 percent NPK (as per KAU POP recommendation)

T_2 : 100 percent NPK

T_3 : 150 percent NPK

T_4 : 100 percent NPK + lime @ 600 kg ha^{-1}

T_5 : 100 percent NPK +CuSO4 5 kg ha^{-1} (if deficiency symptoms appear)

T_6 : 100 percent NP

T_7 : 100 percent N

T_8 : 100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_9 : 50 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)

T_{10} : 100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)

T_{11} : 50 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)

T_{12} : Absolute control (No fertilizer)

4.3.10.2 Available Phosphorus

It can be seen from table 18 that the mean values in the case of available P ranged from 12.54 to 21.29 kg ha^{-1}. Treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) recorded the highest mean value of available P (21.29 kg ha^{-1}) and was found to be on par with treatment T_{10} (100 per cent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)) (21.21 kg ha^{-1}). The lowest value of available P, 12.54 kg ha^{-1} was recorded by T_{12} (absolute control) which was significantly inferior to all other treatments.

4.3.10.3 Available Potassium

Various treatments significantly influenced the available potassium content of soil (Table 18). The mean values ranged from 54.61 to 97.79 kg ha^{-1}. The treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) registered the highest mean (97.79 kg ha^{-1}) which was on par with T_3 (93.11 kg ha^{-1}) and T_{10} (93.01 kg ha^{-1}). The lowest value of 54.61 kg ha^{-1} was recorded by T_7 (100 per cent N) which was significantly inferior when compared to all other treatments.

4.4 Correlation Studies

The data were further subjected to the statistical tool of correlation analysis to study the relationship of each of the soil biological property with grain yield with respect to each experiment. Simple correlations were worked out between the independent variable *viz.* biological property (X) and dependant variable, grain yield (Y) and are presented in Table 19 (Permanent Manurial Trial with tall indica rice variety), Table 20 (Permanent Manurial Trial with dwarf indica rice variety) and Table 21 (AICRP on long term fertility experiment).

As can be observed from Table 19 significant positive correlation existed for the grain yield of (PMT- Tall) with arthropod count (r = +0.462), bacterial count (r = 0.426), actinomycetes count (+ 0.355), fungal count (r = +0.613) and soil carbon mineralisation potential (+ 0.350).

In (PMT- Dwarf) grain yield has significant positive correlation (Table 20) with soil fungal count (r = +0.426), Azotobacter count (r = +0.554), P- solubilizers count (r = + 0.369), microbial biomass carbon (r = + 0.368) and nitrogen mineralisation potential of soil (r = +0.486).

In AICRP on LTFE yield was correlated positively and significantly with all the soil biological properties studied as evident from Table 21.

Table 19. Simple correlations (PMT- Tall)

Sl. No.	Biological Parameters	Coefficient of correlation (r) for grain yield
1	Arthropods	0.462*
2	Bacteria	0.426*
3	Actinomycetes	0.355*
4	Fungi	0.613*
5	*Azospirillum*	0.049
6	*Azotobacter*	0.132
7	P solubilizers	0.334
8	Urease	0.227
9	Phosphatase	0.169
10	Dehydrogenase	0.295
11	Soil respiration	0.337
12	Microbial biomass carbon	0.330
13	Carbon mineralization potential	0.350*
14	Nitrogen mineralization potential	0.162
15	Hot water extractable soil carbohydrates	0.169

* Significance at 0.05 level

Table 20. Simple correlations (PMT- Dwarf)

Sl. No.	Biological Parameters	Coefficient of correlation (r) for grain yield
1	Arthropods	0.309
2	Bacteria	0.188
3	Actinomycetes	0.172
4	Fungi	0.426*
5	*Azospirillum*	0.126
6	*Azotobacter*	0.554*
7	P solubilizers	0.369*
8	Urease	0.198
9	Phosphatase	-0.040
10	Dehydrogenase	0.322
11	Soil respiration	0.058
12	Microbial biomass carbon	0.368*
13	Carbon mineralization potential	0.339
14	Nitrogen mineralization potential	0.486*
15	Hot water extractable soil carbohydrates	0.262

Table 21. Simple correlations (LTFE)

Sl. No.	Biological Parameters	Coefficient of correlation (r) for grain yield
1	Earthworms	0.649*
2	Arthropods	0.391*
3	Bacteria	0.828*
4	Actinomycetes	0.763*
5	Fungi	0.707*
6	*Azospirillum*	0.745*
7	*Azotobacter*	0.675*
8	P solubilizers	0.398*
9	Urease	0.733*
10	Phosphatase	0.717*
11	Dehydrogenase	0.727*
12	Soil respiration	0.633*
13	Microbial biomass carbon	0.813*
14	Carbon mineralization potential	0.908*
15	Nitrogen mineralization potential	0.774*
16	Hot water extractable soil carbohydrates	0.853*

* Significance at 0.05 level

4.5 Regression Studies

Table 22. Multiple regression co-efficients indicating contribution of soil biological properties to yield (PMT- Tall)

Sl. No.	Biological property	Regression co-efficient ('t' value in bracket)
1	Arthropod population	+5.02 (+1.39)
2	Bacterial population	+4.77 (+0.73)
3	Actinomycetes population	+10.28 (+0.96)
4	Fungal population	+10.89 (+1.51)
5	*Azospirillum* population	-4.71 (-1.07)
6	*Azotobacter* population	-4.39 (-0.40)
7	P solubilizers population	+55.01 (+1.06)
8	Urease activity	+0.07 (+0.04)
9	Phosphatase activity	-4.75 (-0.45)
10	Dehydrogenase activity	-1.06 (-0.66)
11	Soil respiration	+128.09 (+1.33)
12	Microbial biomass carbon	+0.49 (+0.41)
13	Carbon mineralisation potential	+236.69 (+0.98)
14	Nitrogen mineralisation potential	+1.99 (+1.15)
15	Hot water extractable soil carbohydrates	-0.22 (-1.58)
	R^2	0.725

The data on grain yield and biological properties of the three experiments were further subjected to multiple regression analysis to study the extent of contribution of each individual biological property to yield. The results are presented in Table 22 (Permananet Manurial Trial), Table 23 (Permanent Manurial Trial) and Table 24 (AICRP on Long Term Fertilizer Experiment). Out of the 15 biological properties studied in the case of (PMT- Tall) none of the properties contributed significantly to yield individually as evidenced by the correlation‘t’ values. For (PMT- Dwarf) yield was influenced to the maximum extent by microbial biomass carbon (-4.11) while carbon mineralisation potential contributed the maximum to yield (+4.47) for LTFE.

Table 23. Multiple regression co-efficients indicating contribution of soil biological properties to yield (PMT- Dwarf)

Sl. No.	Biological property	Regression co-efficient ('t' value in bracket)
1	Arthropod population	+6.48 (+0.26)
2	Bacterial population	-4.36 (-0.39)
3	Actinomycetes population	-0.62 (-0.03)
4	Fungal population	+29.18 (+0.73)
5	*Azospirillum* population	-10.51 (-0.30)
6	*Azotobacter* population	+1.21 (+0.04)
7	P- solubilizers population	-45.59 (-0.42)
8	Urease activity	+12.29 (+1.95)
9	Phosphatase activity	-3.78 (-0.34)
10	Dehydrogenase activity	+1.37 (+0.29)
11	Soil respiration	+1.08 (+0.12)
12	Microbial biomass carbon	-10.37 (-4.11)*
13	Carbon mineralisation potential	+4.28 (+1.04)
14	Nitrogen mineralisation potential	-3.59 (-3.59)*
15	Hot water extractable soil carbohydrates	-0.18 (-0.77)
	R^2	0.873

Table 24. Multiple regression co-efficients indicating contribution of soil biological properties to yield (LTFE)

Sl. No.	Biological property	Regression co-efficient ('t' value in bracket)
1	Earthworm population	+4.81 (+0.74)
2	Arthropod population	-0.65 (-0.56)
3	Bacterial population	-1.29 (-0.43)
4	Actinomycetes population	-5.64 (-1.80)
5	Fungal population	+7.27 (+2.23)*
6	*Azospirillum* population	+4.90 (+1.79)
7	*Azotobacter* population	+6.38 (+1.77)
8	P solubilizers population	+34.14 (+2.25)*
9	Urease activity	+1.91 (+1.43)
10	Phosphatase activity	-8.69 (-1.44)
11	Dehydrogenase activity	+0.93 (+2.09)*
12	Soil respiration	-100.26 (-3.03)*
13	Microbial biomass carbon	+0.39 (+0.85)
14	Carbon mineralisation potential	+1452.25 (+4.47)*
15	Nitrogen mineralisation potential	-0.94 (-1.07)
16	Hot water extractable soil carbohydrates	+0.06 (+1.14)
	R^2	0.950

Discussion

5. DISCUSSION

The salient results of the laboratory investigations carried out at College of Agriculture, Vellayani to understand the variations in the biological properties of the ferralitic alluvial soils of Regional Agricultural Research Station, Pattambi under three long term fertilizer experiments *viz*. Permanent Manurial Trial with tall indica rice variety (PMT- Tall), Permanent Manurial Trial with dwarf indica rice variety (PMT-Dwarf) and AICRP on Long Term Fertilizer Experiment (LTFE) are briefly discussed in this chapter. The data on soil parameters relate to Kharif crop, 2012-13 of the experiments as the post harvest soil samples of these crops formed the study material for the microbiological/ biochemical assays for studying the biological properties of these soils. As the influences of these properties are naturally bound to be reflected on the yield and yield bearing components of the succeeding crops raised on these soils the plant characters considered for the study were related to the Rabi crop (2012-13) of these experiments which were collected from the field registers maintained at RARS, Pattambi. For all the experiments rice-rice cropping sequence was followed.

5.1 SOIL MACROFAUNA

5.1.1 Earthworms

Earthworms are extremely important for the maintenance of soil porosity and nutrient cycling. They generally increase microbial activity through their castings as well as their pedoturbation activity which is reported to enrich the surface soil layers with essential nutrients translocated upward from deeper soil layers. A count of ten earthworm ft^{-2} of soil is generally considered as a good population in agricultural system. Earthworm counts could be taken only for LTFE (Figure 5.) as the soil temperatures of both the PMT experimental fields were too high for their survival. In LTFE treatment, T_8 involving the combination of FYM and inorganic fertilizers recorded the highest earthworm population of 16.25 no. m^{-2} soil. The observation is in agreement with findings of Marhan and Scheu (2005). They reported that NPK+FYM application in soil increased earthworm biomass by 42.8 per cent due to increase in the utilizable soil organic

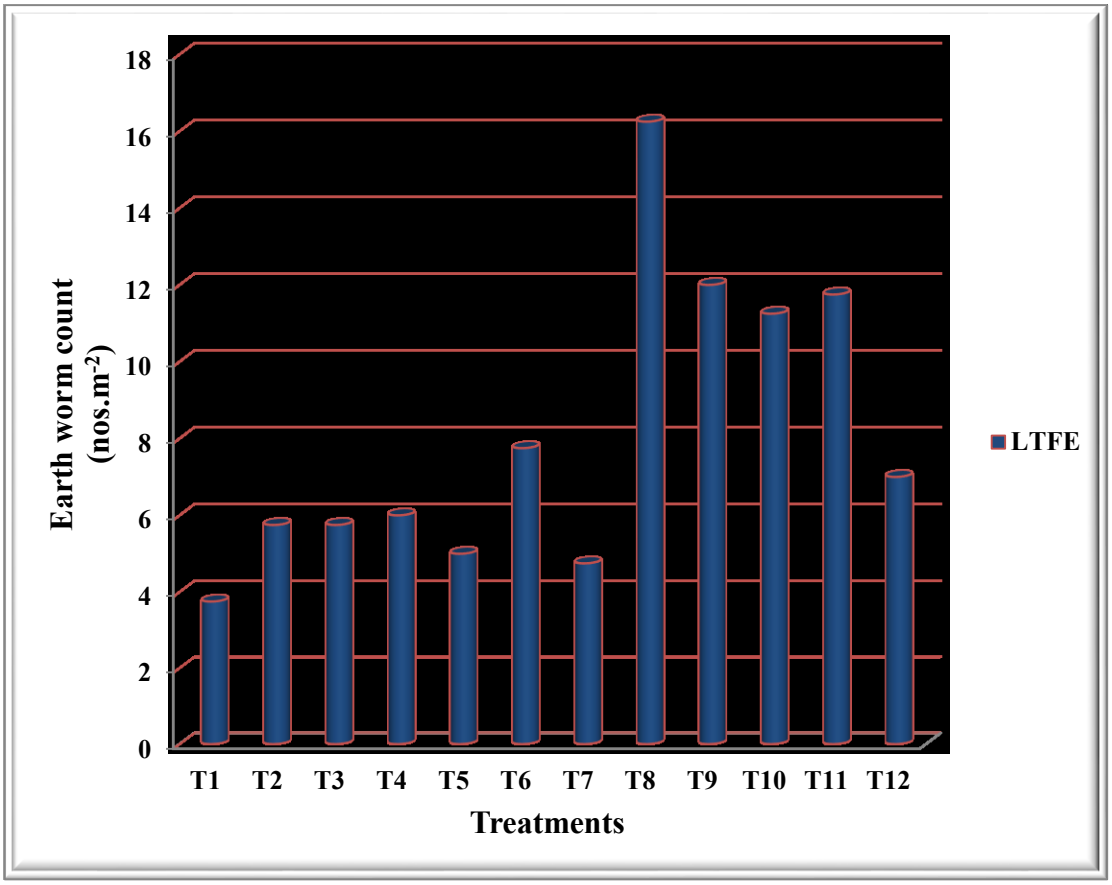


Figure 5. Effect of treatments on Earthworm count on LTFE.

matter in native soil pool. As this treatment included the dual sources of the full dose of all the major nutrients *viz*. organic as well as inorganic of the full dose of all the major nutrients N, P and K the multiplication of the native earthworms might have been greatly favoured compared to other treatments which received only inorganic sources of nutrients or the dual sources of 50 per cent of the major nutrients. According to Edwards *et al*. (1995) addition of organic material can double or triple earthworm number in a single year.

5.1.2 Arthropods

The arthropods in soil include mainly the collembolas and mites and their habitation in soil is considered to be an indicator of redistribution of organic matter, humification, organic matter break down and comprehensive ecological restoration.

The different treatments of all the three experiments had profound influence on arthropod population. Higher arthropod counts were recorded for the treatments which had the combinations of both organic manures and inorganic fertilizers (Figure 7). Observations are in agreement with the findings of Olla *et al.* (2013) who found that of poultry manure significantly improved their population and particularly that of collembola by about 48.48 per cent over that of the control plots. Sjursen *et al.* (2005) studied the effect of long term fertilisation on micro arthropod population and reported that inorganic fertilization increased population of micro arthropods. Application of organic manures and inorganic fertilizers can positively but indirectly affect soil fauna by increasing plant growth and stimulating root exudation, both of which lead to a greater input of organic substrates. Scholte and Lootsma (1998) studied the effect of FYM and green manure crops on populations of mycophagous soil fauna and found that FYM had a stimulative effect on micro arthropods. Similarly Axelsen and Kristensen (2000) from studies on collembola and mites in plots fertilized with different types of green manures reported that the input of organic matter in various forms, such as green manures and crop residues, increased populations of micro arthropods. Organic matter is crucial for the stability of soil structure and serves as an energy

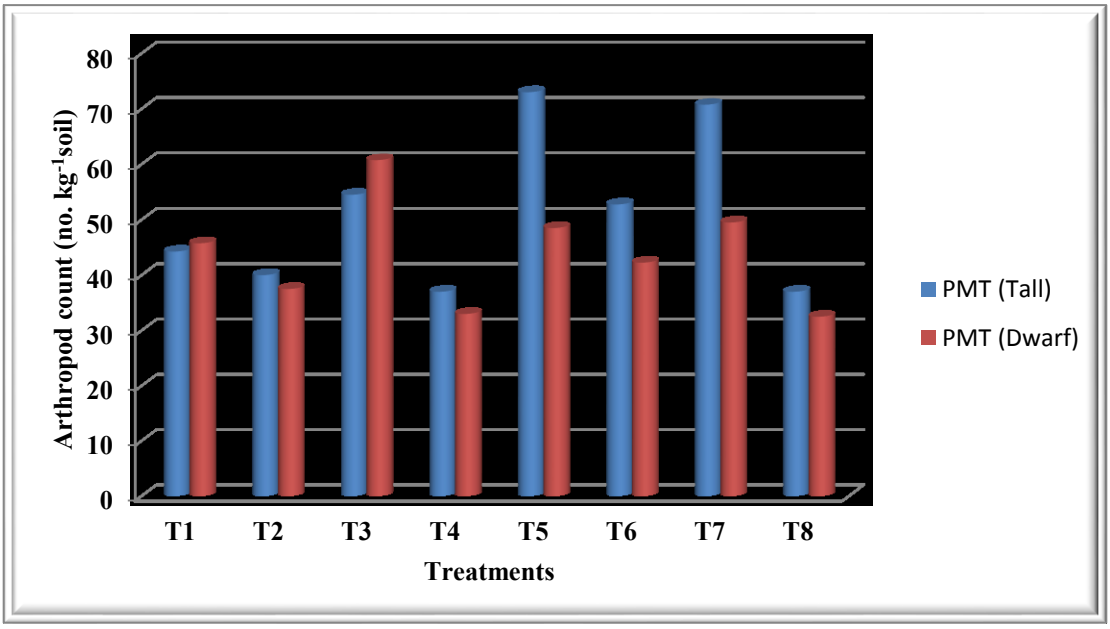


Figure 6. Effect of treatments on Arthropods count on (PMT- Tall) and (PMT-Dwarf)

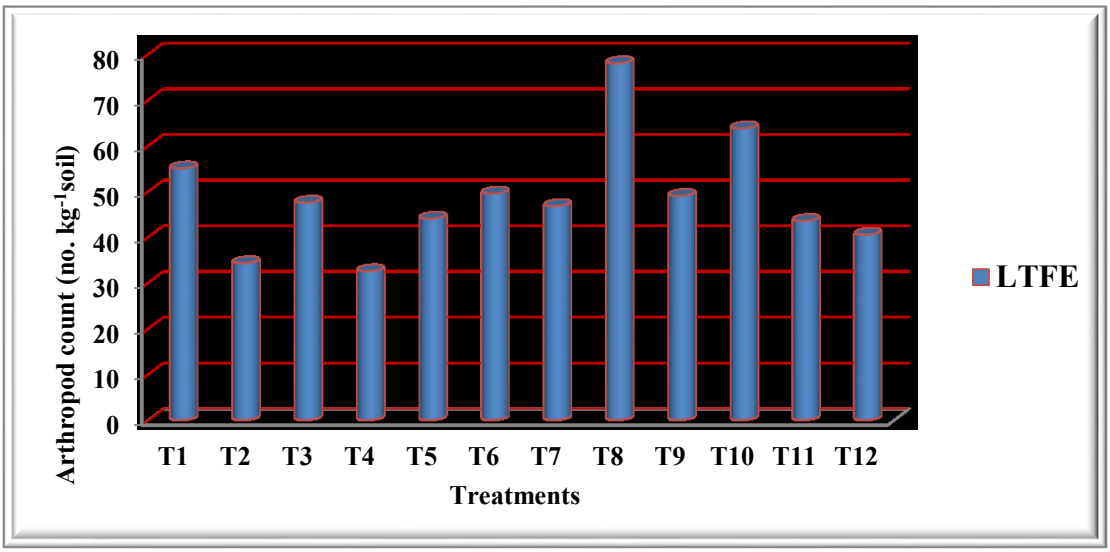


Figure 7. Effect of treatments on Arthropods count on LTFE.

source for microorganisms which mesofauna like the arthropods consume. Both in (PMT- Tall) and (PMT- Dwarf) the lowest arthropod count was recorded for treatment with inorganic fertilizers alone (Figure 6). The use of urea as the N source might be the major reason for the lower population of the arthropods. Urea is known to decrease the soil pH through increase in nitrate ions. The acidity of soil can exert a depressing effect on many Collembolan species of micro arthropods. Nitrogen fertilizers without organic matter addition can also create a high osmotic pressure in soil solution which has a negative effect on the abundance of soil fauna (Andren, 1984).

5.2 SOIL MICROFLORA

Soil harbours a dynamic population of microorganisms and they play a vital role in decomposition of organic matter, phosphate solubilisation, N transformation, humification of organic residues and several other biochemical soil reactions of importance in plant nutrition

5.2.1 B**acteria**

The results revealed that among the microbes, the total bacterial populations were higher than that of fungi, actinomycetes, *Azospirillum*, *Azotobacter* and P soubilizers. In (PMT- Tall) treatment T_7(10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest bacterial count. Soil bacteria usually show increase in population with incremental doses of N. In (PMT-Dwarf) also treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) recorded the highest population. The possible reason for this could be the enhanced organic carbon content of soil as a result of organic manure application. Besides this, the organic manure addition would have resulted in increased amount of secondary and micronutrients in the soil which might have helped in increasing the microbial population. Results are in agreement with that of Biederbeck *et al*. (2005) who found that inclusion of green manure in a continuous wheat system gave higher microbial count including bacteria. In the case of LTFE treatment T_8 (100 percent NPK + FYM @ 5t ha^{-1} (to Kharif crop only)) had the

highest count. This is in agreement with observation of Selvi *et al.* (2004) who found out that the continuous intensive cultivation and fertilization in an Inceptisol recorded the highest bacterial counts with the addition of FYM along with 100 percent NPK. Addition of organic manures favoured a significantly greater input of organic carbon, which increased the bacterial populations (Fraser *et al.,* 1988). The long term application of high levels of N as well as FYM produces favourable effect on soil bacteria as a result of bringing about higher organic carbon, good physical properties and lower bulk density of soil.

5.2.2 Actinomycetes

In both (PMT- Tall) and (PMT- Dwarf), the treatment combination of organic manure, green manure and inorganic fertilizers recorded the highest actinomycetes population. In LTFE the treatment with application of FYM and inorganic fertilizers recorded the highest actinomycetes count. The results are in agreement with those of Swarup (2000) and Selvi *et al*. (2004) who found out that continuous application of FYM with NPK resulted in greater counts of actinomycetes. The possible reason for this could be the enhanced organic carbon content of soil due to addition of organic manure along with NPK application.

5.2.3 Fungi

In (PMT- Tall) treatment T_7(10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest fungal count and T_1 (40 kg N ha^{-1} as cattle manure) was found to be on par with T_7. The lowest count was for treatment T_8 (NPK @ 40:20:20 kg ha^{-1}). These results are substantiating the findings of Venkateswarlu (2000) and Sharma *et al.* (1983). They found greater fungal populations in FYM treated plots as compared to application of chemicals alone. In (PMT- Dwarf) higher fungal count was found in treatment T_6 (45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}) which was found to be on par with T_5 (45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) and T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}). Fungal activity generally increase in green manure applied plots since narrow carbon nitrogen ratio of green manure easily furnishes

N stimulating fungal growth. In LTFE the treatment T_8 with application of FYM and NPK recorded the highest fungal growth. Swer *et al.* (2007) reported that fungal population was comparatively higher in organically amended plots as compared to control.

5.2.4 *Azospirillum*

The highest *Azospirillum* population in (PMT- Tall) experiment was recorded by treatment T_3 (20 kg N ha^{-1} as cattle manure + 20 kg ha^{-1} as green leaf). Veeraputhran (2000) reported that application of green manure (*Sesbania*) @ 6.25 t ha^{-1} + *Azospirullum* (2 kg ha^{-1}) took significantly shorter period for 50 per cent flowering and produced the highest number of productive tillers m^{-2} and filled grains $panicle^{-1}$. In case of (PMT- Dwarf) the highest population was for treatment T_6 (45 kg N ha^{-1} as green manure+ NPK @ 45:45:45 kg ha^{-1}). Treatment T_8 which supplied both FYM and NPK recorded higher count of *Azospirillum* in LTFE fields.

5.2.5 *Azotobacter*

It is evident from the data generated out of the experiments that the *Azotobacter* count was profoundly influenced by different treatments. In (PMT- Tall) treatment T_7(10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest *Azotobacter* population. In (PMT-Dwarf) also treatment T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) recorded the highest count. In LTFE the highest population of *Azotobacter* was observed for the treatment T_8 (100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)). These results are in agreement with the observations of Jain *et al*. (2003) who reported that FYM + 100 per cent NPK increased the population of *Azotobacter* in comparison to treatments not having FYM.

5.2.6 P Solubilizers

In tall indica variety experiment in the case of P Solubilizers treatment T_5 (20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest

population. In the case of Dwarf indica variety also treatment T_5 (45 kg N ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) reported highest count. In LTFE highest population was observed for treatment T_2 (100 percent NPK) which was on par with T_3 (150 percent NPK), T_8 (100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)). The enhancement of available P might be due to soluble P contributed from the mineral fertilizers added by the mineralization action of the P solubilizing bacteria, because many soil microorganisms are able to transform insoluble forms of P to usable soluble form. Increase in available P content of soil, with the addition of fertilizers along with manures was reported by Sharma *et al.* (2005).

5.3 SOIL ENZYMES

Soil enzymatic assays act as potential indicators of ecosystem quality being operationally practical as well as sensitive and are integratively described as 'biological finger prints' of past and present soil management. Quantitative measurement of these enzyme activities can contribute to understanding of transformations by facilitating the evaluation of microbes present in soil. Measurement of activity of extracellular enzymes provides information on the biological activities of microorganisms.

5.3.1 Urease

A critical perusal of data given in Table 3 shows that in (PMT- Tall) the treatment involving the combination of inorganic fertilizers with FYM and green manure (T_7) was significantly superior to other treatments, recording the highest value for urease activity (Figure 8). This increase in urease activity may be attributed to the altered soil characteristics, biological richness and associated beneficial effects conferred by the application of this integrated treatment over several seasons and years. Increased urease activity in manured plots in combination with fertilizers might be due to the high amounts of urease contributed by the viable microbial population and to the elevated levels of accumulated urease from dead biomass. Results in the same line were reported by Dick *et al*. (1988). In (PMT- Dwarf) also treatment combination T_7 (22.5 kg N ha^{-1} as green leaf + 22.5 kg N

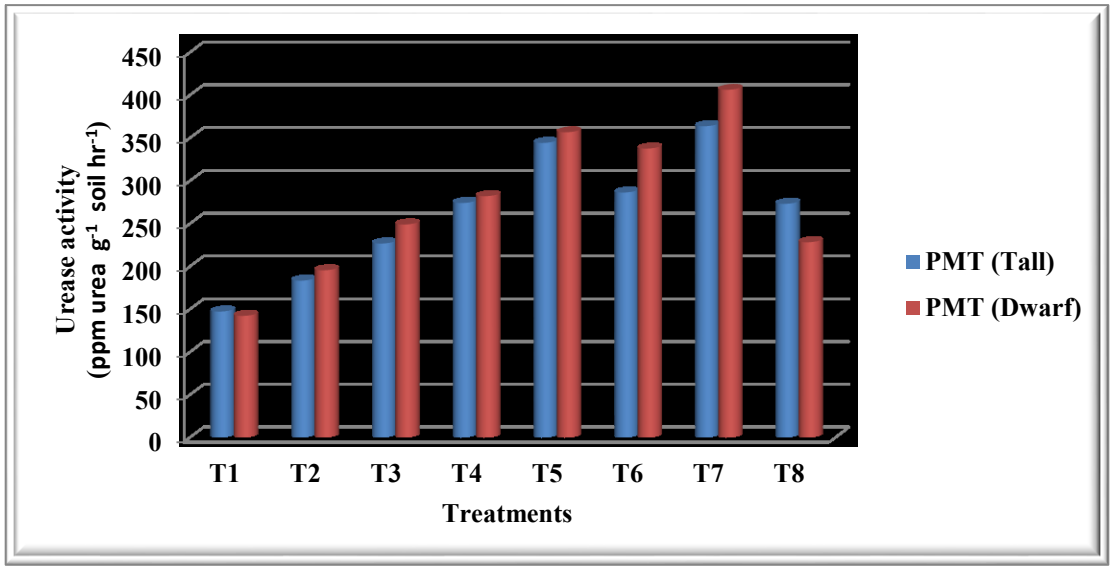


Figure 8. Effect of treatments on urease enzyme activity- (PMT- Tall) and (PMT-Dwarf)

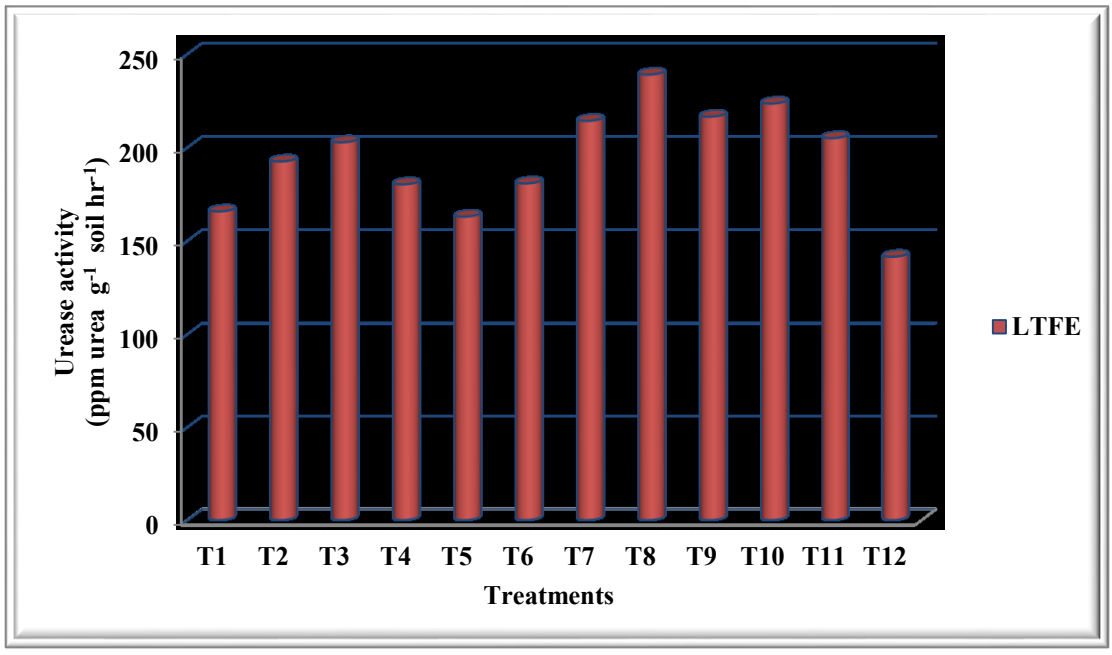


Figure 9. Effect of treatments on urease enzyme activity- LTFE

ha^{-1} as cattle manure + NPK @ 45:45:45 kg ha^{-1}) recorded the maximum value for urease activity. In LTFE treatment T_8 with application of both FYM and NPK showed the highest activity (Figure 9). These findings corroborate with findings of Rai and Yadav (2011) who reported that the combined application of organic and inorganic sources of major plant nutrients showed higher values for soil urease activity 60 days after incubation. It is also noteworthy that treatment involving application of cattle manure alone reported very low values highlighting the need of inorganic sources to stimulate the enzyme activity. This is an agreement with the findings of Frankenberger and Dick (1983). According to them factors like higher population of ureolytic bacteria and higher amount of organic carbon contribute to increased urease activity.

5.3.2 Phosphatase

Under rice culture at Pattambi, the treatment involving the application of green leaf and cattle manure along with N, P, K fertilizers (T_7) recorded the highest activity for phosphatase enzyme in (PMT- Tall) indicating the beneficial effects of organic sources of nutrients (Figure 10). Treatment T_1 (cattle manure alone) applied plots showed very low activity of phosphatase. This observed positive effects of N, P, K fertilizers and organic manures on phosphatase activity might be due to the capacity of this treatment to supply mineral nutrients, C and energy for the fast multiplying microorganisms producing phosphatases. The proliferation of non-specific microorganisms, less sensitive to high available P in soil may be the reason for the contribution to phosphatase both from living and dead cells. Hence, phosphatase derived through these sources might have enhanced the total phosphatase activity of the soil. The results are in agreement with the findings of Haynes and Swift (1988). In (PMT- Dwarf) experiment also the highest value of phosphatase activity was noticed for the treatment T_7 with application of organic manure, green manures and inorganic fertilizers. Similar trend was noticed for LTFE also, the highest activity of phosphatase being observed for treatment with application of both FYM and NPK (Figure 11).

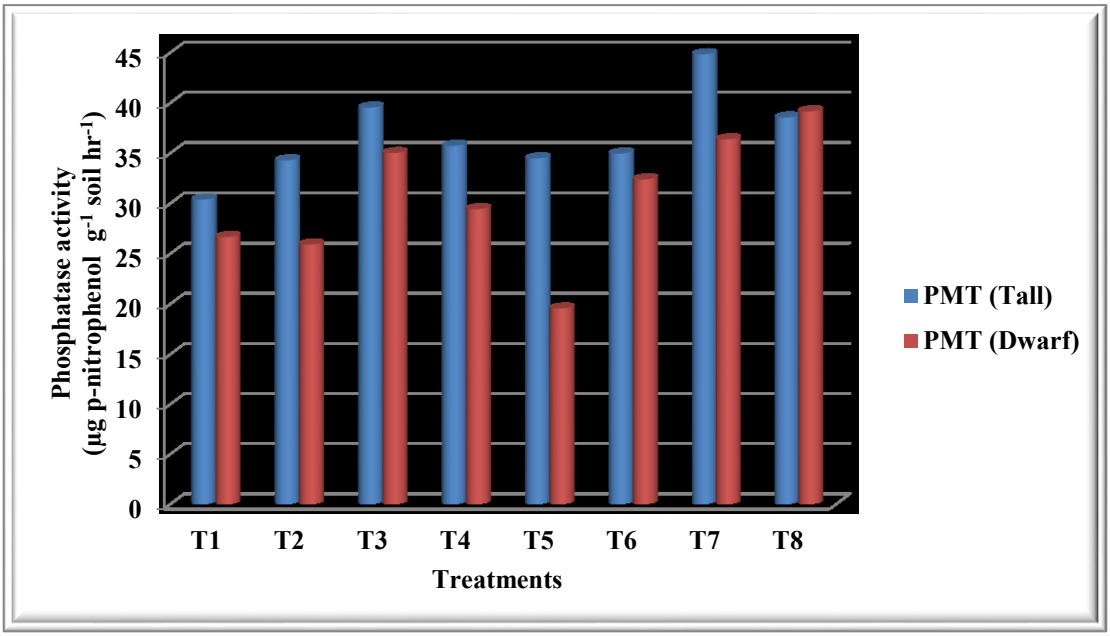


Figure 10. Effect of treatments on phosphatase enzyme activity- (PMT- Tall) and (PMT- Dwarf)

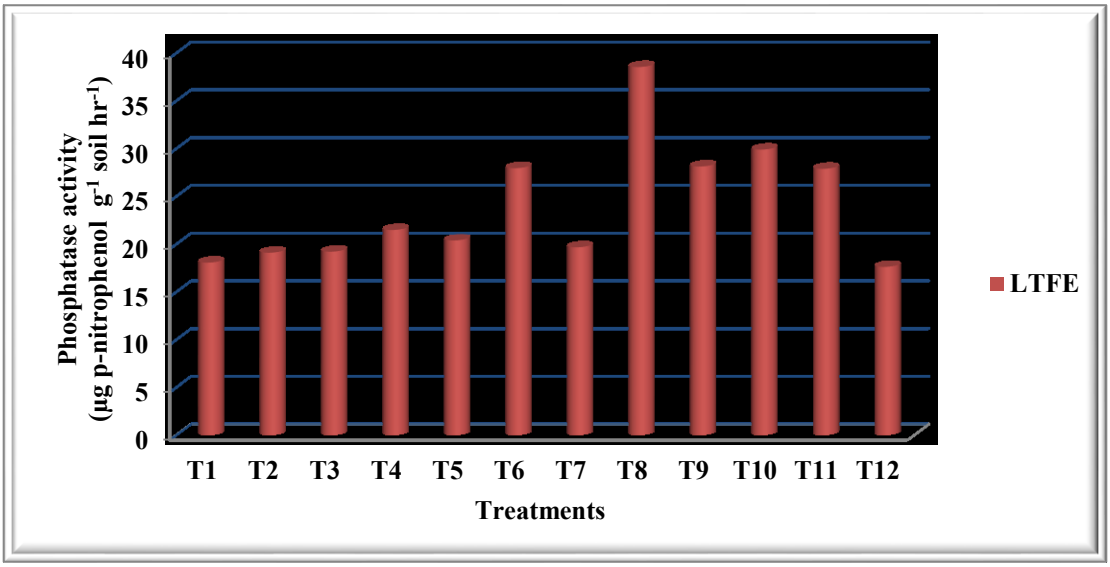


Figure 11. Effect of treatments on phosphatase enzyme activity- LTFE

Changes in phosphatase activity in response to inorganic fertilizers were non-significant. Enhanced alkaline phosphatase activities in response to manure application have been reported by Parham *et al.* (2002). As phosphatase activity has shown to be highly correlated with both microbial population and total biomass in soil (Frankenberger and Dick, 1983) it is logical to observe greater activity in plots treated with organic amendments. Harrison (1983) suggested a positive relationship between phosphatase and organic matter content since the enzyme was seen bound to humic- protein complex. The lowest value was recorded for the application of N, P and K at the rate of 90:45:45 kg ha^{-1}. The decrease in phosphatase activity consequently to higher doses of mineral P could be attributed to the reduced activity of phosphorus solubilizing organisms in response to a high available P. Thus the maximal activity of phosphatase could be observed only in plots receiving minimum inorganic P. Organic fertilization resulting in significant increase in the activity of phosphatase has been reported by Kalembasa and Kuziemska, (2010).

5.3.3 Dehydrogenase

Dehydrogenase activity of a soil is directly related to the active microbial population inhabiting it as this enzyme has been recognised as a strictly endocellular enzyme. Dehydrogenase exists as integral parts of intact cells and reflects the total range of oxidative activities of soil microflora. Due to these obvious reasons dehydrogenase activity has been accepted as a sensitive tool for discriminating the treatment effects due to various soil management practices. The highest dehydrogenase activity was observed for treatment T_7 involving cattle manure and green manure in combination with inorganic fertilizers in (PMT- Tall) (Figure 12). Addition of organic sources acts as good source of carbon and energy to heterotrophs by which their population increase with an increase in enzyme activities. In addition to soil microorganisms soil microflora, plant roots and plant residues undergoing varying degrees of decay also contribute to this pool. Similar observations have been reported by many researchers like Chendrayan *et al*. (1980); Pedrazzeni and McKee, (1984) and Kalidurai, (1988).

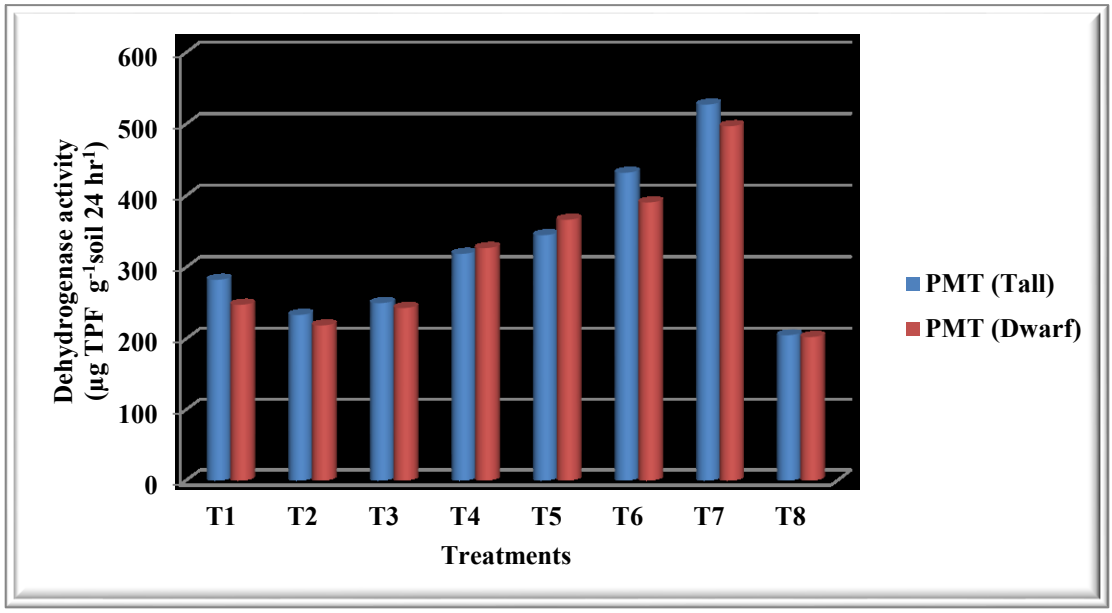


Figure 12. Effect of treatments on dehydrogenase enzyme activity- (PMT- Tall) and (PMT- Dwarf)

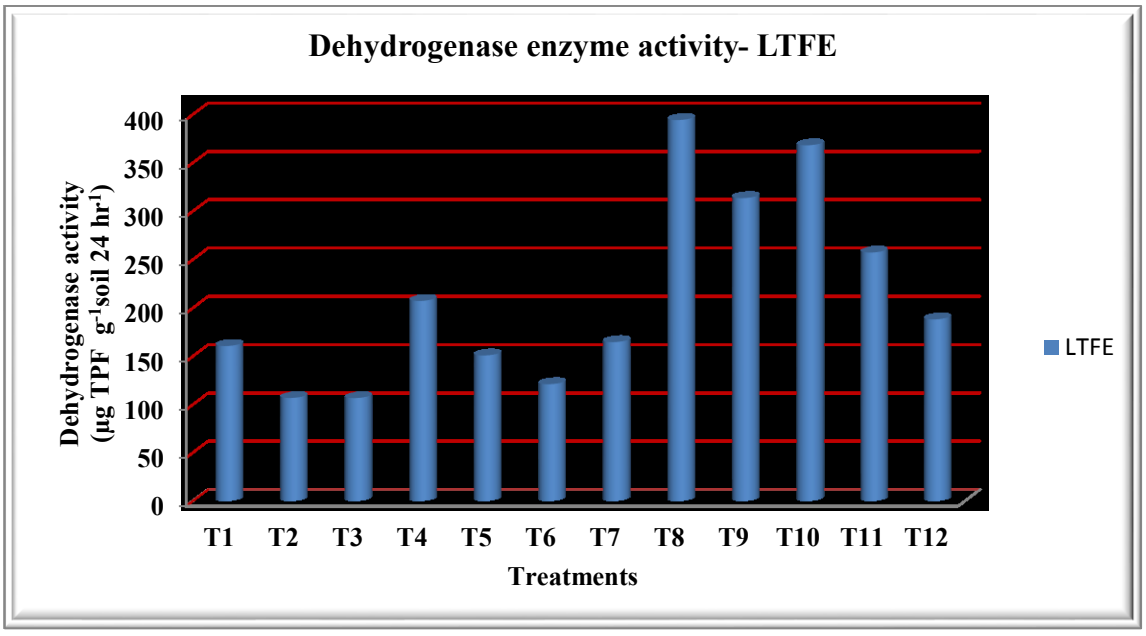


Figure 13. Effect of treatments on dehydrogenase enzyme activity- LTFE

This observation was further substantiated by Eiland (1980) who obtained significantly higher activity of dehydrogenase in fertilized plots compared to unfertilized plots in a Danish long term experiment. From this investigation, it could be seen that a nutrient rich environment coupled with high C and energy source was mandatory for the enhanced activity of dehydrogenase and the elimination of any one of the nutrients resulted in its lower activity.

In (PMT- Dwarf) also treatment combination T_7 which involves the combined application of organic manures and inorganic fertilizers recorded the highest dehydrogenase activity. Organic systems, which used crop residues and green manures in combination with chemical fertilizers were found to have higher dehydrogenase activity than the conventional systems according to the report of Bolton *et al*. (1985). The dehydrogenase activity has been often linked with the levels of available C substrates in the soil, as they serve as the source of electrons and H+ for accomplishing reduction reactions. The higher levels of dehydrogenase activity observed at the RARS, Pattambi in the manured rice plots might be due to the higher organic C and nutrient status. It can also be inferred that the dehydrogenase activity increased with increasing microbial population following the application of organic amendments with mineral nutrients as evident from the results of the LTFE at Pattambi for which this treatment registered the maximum dehydrogenase activity (Figure 13). The result goes hand in hand with the finding of Ladd and Paul (1973). Bhattacharyya *et al*. (2008) reported that long term applications of FYM @ 10 t ha^{-1} with 100 per cent NPK recorded significantly higher dehydrogenase activity compared to other treatments. Similarly Babita *et al*. (2012) based on long term fertilizer experiments reported that the dehydrogenase enzyme activity corresponding to all nutrient management practices was higher than that of the control plot and reached its maximum in the 100 per cent NPK+FYM treated plot. Thus the change in dehydrogenase activity corresponds more closely to microbial biomass generated through an enhanced microbial activity rather than the direct nutritional or amended effect. Hence, dehydrogenase activity will be more a representative index of the long term soil

management practices especially manuring. This view is in accordance with the findings of Burns (1982).

5.4 SOIL RESPIRATORY ACTIVITY

Soil respiration rate as assessed by CO_2 evolution is an indicator of biological activity and hence the biological health of soil. According to Santruckova (1993) it is a strong indicator of the soil metabolic and ecological functions.

A critical examination of the data obtained from (PMT- Tall) of the RARS, Pattambi reveals significant effect for the treatments on respiratory activity (Table 3). The highest value was recorded for the treatment T_5 receiving combined application of chemical fertilizers with FYM (Figure 14). Faster multiplication of microflora in response to an abundant source of energy rich compounds, carbon and nutrients derived from the added organics and chemical fertilizers could be attributed to this observation. Similar results have been reported by Cochran *et al*. (1988). In the (PMT- Dwarf) also treatment T_6 involving the application of green manures with combination of inorganic fertilizers registered the highest value (Table 9). In LTFE treatment T_8 which involves a combination of FYM and NPK registered the highest soil respiration (Figure 15). The combined application of manures and fertilizers provide a balanced supply of carbon, energy and mineral nutrients which increase the microbial activity and substrate induced respiratory activity. Thus even with moderately high organic sources, supplementary addition of chemical fertilizers could improve the activity of sol microflora substantially to produce high respiratory activity as reported by Wheatley *et al*. 1990.

5.5 MICROBIAL BIOMASS CARBON

Brookes (1995) reported that microbial biomass is a sensitive parameter which can be used as an early warming of changes in soil biological ecosystem before they are detectable in other ways.

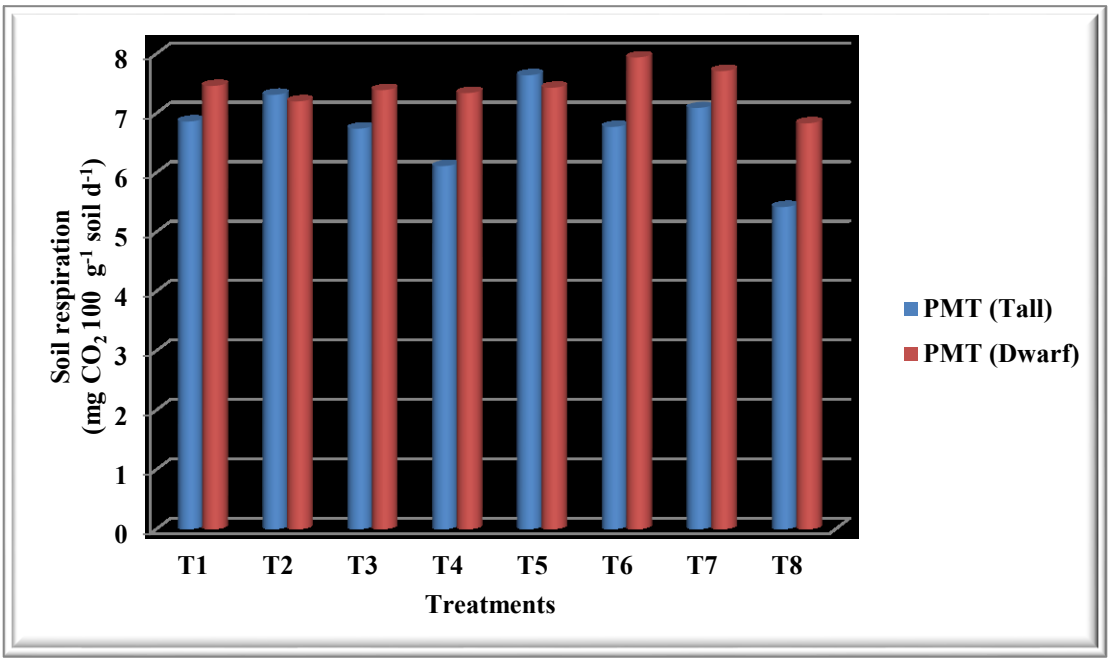


Figure 14. Effect of treatments on soil respiration - (PMT- Tall) and (PMT- Dwarf)

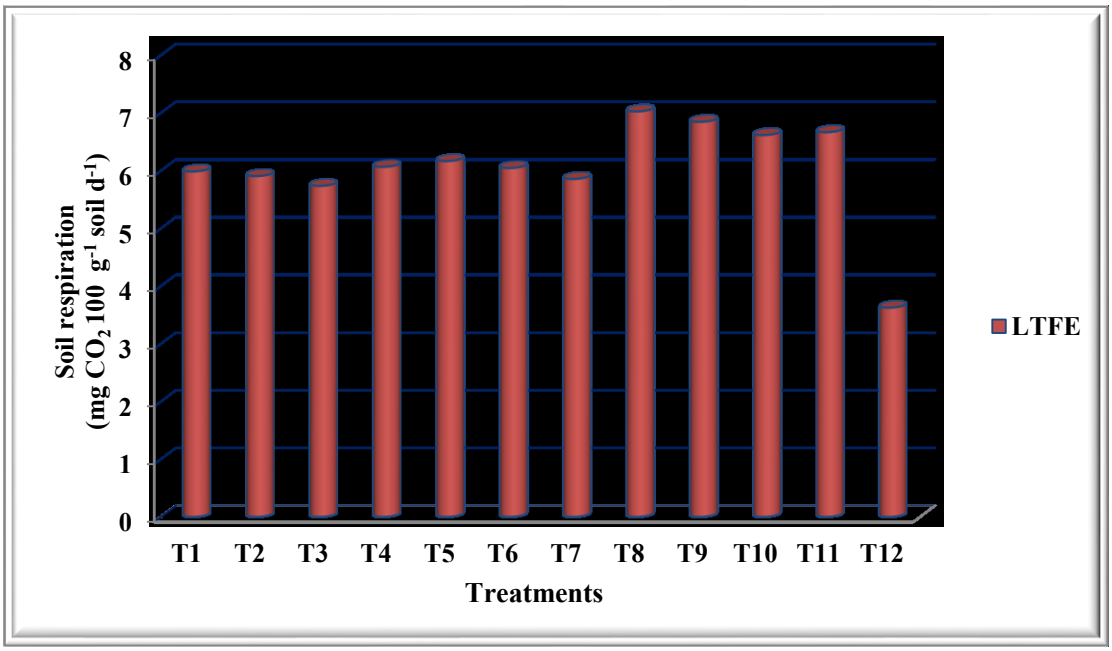


Figure 15. Effect of treatments on soil respiration - LTFE

It is evident from the data that the microbial biomass carbon was profoundly influenced by different treatments. In (PMT- Tall) the highest MBC value was recorded for treatment T_7 involving the application of green manures with combination of organic and inorganic fertilizers. In (PMT- Dwarf) also the same treatment combination recorded the maximum value. Marumoto (1984) opined that the addition of N, P and K fertilizers conjunctively with manures almost doubled the microbial biomass carbon compared to the generated values in soils treated with inorganic fertilizers alone. Similar observations were made by Goyal *et al*. (1999), Lalande *et al*. (2000), and Saini *et al*. (2004). In the case of LTFE treatment T_8 involving the combination of organic and inorganic fertilizers recorded the maximum value. The observations are in agreement with Surekha *et al*. (2004) who proposed that in plots treated with FYM and NPK there is a build up of soil biomass carbon and N by the enhanced activity of microorganisms. The same is true for crop residues, since due to the slow decomposition of paddy straw, there was positive influence on the build up of organic carbon of soil, microbial activity and availability of soil nutrients and micronutrients. Similarly Manna *et al*. (2005) and Bhattacharyya *et al*. (2008) studied the long term effect of fertilizers and manure application and concluded that microbial biomass carbon improved with addition of NPK and FYM.

5.6 CARBON MINERALISATION POTENTIAL

The carbon mineralisation potential of the soils was estimated as the oxidisable organic carbon contents of the soil. Carbon mineralisation is considered to reflect the availability of slow flowing carbon for microbial maintenance and is a measure of basic turnover rates in soil. It has been widely observed that C mineralization rates are higher in soils receiving organic manures compared to unfertilized soils and soils receiving inorganic fertilizers alone.

A close scrutiny of the data generated out of the present study reveals the significant effect of treatments on carbon mineralisation potential. The highest value for carbon mineralisation potential was observed for treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}).

The practice of adding organic manures for building up organic carbon status of the soil is well recognized and advocated and the results of the present study are also in conformity with the reports of several workers. Continuous application of green manure for 12 years sequestrated 1.0 t C ha^{-1} in the 0-15cm soil layer as reported by Prasad *et al*. (1971). In (PMT- Dwarf) the highest value for carbon mineralization potential was recorded for treatment T_1 which supplied N in the form of cattle manure. The organic carbon content of the soil tends to increase with the addition of organic residues in soil. Similar results have been reported by Tisdale *et al*. 1995. Application of cattle manure in higher proportion was reported by Biswas (1982) to increase the soil organic carbon content compared to the application of chemical fertilizers alone. Treatments receiving chemical fertilizers alone recorded invariably low values in all plots. The increase in organic carbon content in the manured plots might be due to the cumulative effects of continuous application of organics as treatments. The above finding goes hand in hand with the reports of Maurya and Ghosh (1972). In LTFE plots the highest carbon mineralisation potential was obtained for the application of inorganic fertilizers with FYM. Similar research findings are reported by Moossa *et al.* (2012) in their experiment that organic carbon contents in soil in 100 per cent NPK+ FYM plot and that in 100 per cent NPK+ *in situ* green manured (daincha) plot were higher than that in the plot receiving inorganic nutrients alone. Organic residue incorporation improving the soil carbon nutrient pool in a gradual manner has been reported Brar *et al.* (2000) and Beena *et al.* (2002). Hence it is clear that organic manures improve soil quality through the enrichment of soil organic carbon. From earlier studies conducted in soils under permanent manurial trials at Pattambi and Kayamkulam, Kurumthottical (1982) reported that application of organic matter either alone or in combination with inorganic fertilizers significantly enhanced the level of soil organic carbon and its mineralisation. Similar observations have been put forth by Rabindra and Honnegowda (1986). This clearly depicts that the application of inorganic fertilizers is also contributing for the improvement of soil quality. Thus the results of the present study provide an indication towards the role of inorganic

fertilizers also for improvement of one of the major soil quality parameters, soil organic carbon.

5.7 NITROGEN MINERALISATION POTENTIAL

The most widely used method for determination of mineralisable or available N in India is the determination based on the alkaline permanganate oxidisable organic N method proposed by Subbiah and Asija (1956). The mineralization potentials of the soils of the three experiments of the present study were also estimated by this method. Most nitrogen (95-99 per cent) in soil is present in organic forms and is available to plants only after mineralization by soil microorganisms. The fraction of organic N released in a given time is usually termed as potentially available N for the crops. It is estimated that one to three per cent of the soil organic N becomes available for plant uptake in an year depending on soil conditions and nature and quality of soil organic N pool.

In the (PMT- Tall) the highest value for N mineralisation potential was recorded for the treatment T_7 receiving cattle manure and green leaf manure in combination with N, P and K fertilizers. In this case treatment receiving combination of both organic and inorganic N sources maintain a higher level of available N consequent to steady mineralisation of organic manures coupled with a supplementary source from inorganic N fertilizers. Thus even after plant uptake this treatment could sustain a higher level of available N in soil. The process of aminisation, ammonification and oxidative deamination all brought about by microbialy mediated system are believed to be active in the organic sources, thus contributing more of soluble N to soil. According to Bitzer and Sims (1988) the narrow C: N ratio achieved in the soil system through the above combination can also trigger an increase in population of microorganisms leading to the synthesis of higher microbial biomass protein which releases N upon decomposition. Organic fertilizers like FYM are known to stimulate biological nitrogen fixation in the soil, which may also be responsible for the increase in soil available N. Plot receiving a combination of cattle manure and green manure as treatment registered higher mineralisation potential in (PMT- Dwarf) also which was on par

with the integrated treatment of cattle manure, green manure and inorganic fertilizer application. In LTFE also the treatment involving the in-situ growing of green manure and inorganic fertilizer recorded the highest N mineralisation potential value. Tiwari *et al*. (1980) observed the beneficial effects of green manuring alone and in combination with fertilizer N in rice and reported the positive effect of green manuring on N mineralisation. Green manures with very low C:N ratio behave similarly to mineral fertilizers and are able to mineralise soil N as evidenced by the results of long-term experiments conducted by Bhandari *et al*. (2002). Saravanapandian and Haroon (2012) and Siddeswaran *et al*. (2012) also reported similar results of effects of green manure, organic manure and inorganic fertilizers on soil available N status.

5.8 HOT WATER EXTRACTABLE SOIL CARBOHYDRATES

Hot water extractable soil carbohydrates are the active components of the soil liable carbon pool and are regarded as the most sensitive measurement for determining the impact of long term nutrient application and residue management (Hazarika and Parkinson, 2011)

Kasia *et al*. (2002) studied hot water extractable soil carbohydrates as influenced by long-term management practices and found that increase in soil organic matter also increased soil hot water soluble carbohydrate concentrations. Different long term treatments of the present investigation profoundly influenced the hot water extractable soil carbohydrates. In both (PMT- Tall) and (PMT- Dwarf) treatment T_7 involving the application of green manures with combination of organic and inorganic fertilizers registered higher values. In LTFE treatment T_8 with combination of organic and inorganic fertilizers registered maximum value. As FYM sustained higher amount of this fraction, their increased levels in plots receiving FYM is quite natural. Hot water extractable carbohydrates were significantly influenced by FYM and NPK application over treatment receiving 100 per cent NPK fertilizer alone as reported by Lalande *et al.* (2000). This indicates that FYM along with inorganic fertilization give extra benefit of carbohydrates. These observations are also in

agreement with the findings of Banwasi and Bajpai (2001) who reported that the FYM along with 100 per cent NPK increased the water soluble carbohydrates over the 100 per cent NPK application alone.

5.9 GRAIN YIELD

In both (PMT- Tall) with tall indica rice variety and (PMT- Dwarf) with dwarf indica rice variety treatment T_7 receiving green manuers, organic manures and fertilizers in combination was significantly superior over other treatments (Figure 16) in producing grain yields of 3563.25 kg ha^{-1} and 3574.00 kg ha^{-1} respectively.

In LTFE also, the treatment involving the application of both organic manure and inorganic fertilizers (T_8) recorded the highest grain yield of 3922.00 kg ha^{-1} (Figure 17). All these results highlight the superiority of the integrated approach in nutrient management for better crop yields. The cumulative effect of favourable biological properties of the soils brought about by these treatments which have been receiving all major plant nutrients steadily through organic as well as inorganic sources over several seasons and years can be attributed to be the reasons for the maximum yields reported for these treatments. All the important biological properties of the soils like populations of earthworms, arthropods, bacterias, actinomycetes, fungi, azospirillum and azotobacter, soil enzymes, MBC, HWC, carbon and nitrogen mineralisation potential, also registered the highest values for these treatments. The values for no.of panicles $plant^{-1}$ and available P and K contents of the soils were also the highest for these treatments. Results are in agreement with those generated by the study by Saravanapandian and Haroon (2012). According to them application of green leaf manure significantly influenced the rice grain yield and the highest grain yield was registered with the application of green leaf manure conjointly with N, P and K fertilizers. Green manure application helps in maintaining prolonged availability of nutrients and improving root penetration, soil physical conditions and nutrient uptake. These results are on the same line with Yadav *et al*. (2005). The problem of accumulation of autotoxins excreted by the roots of rice into the

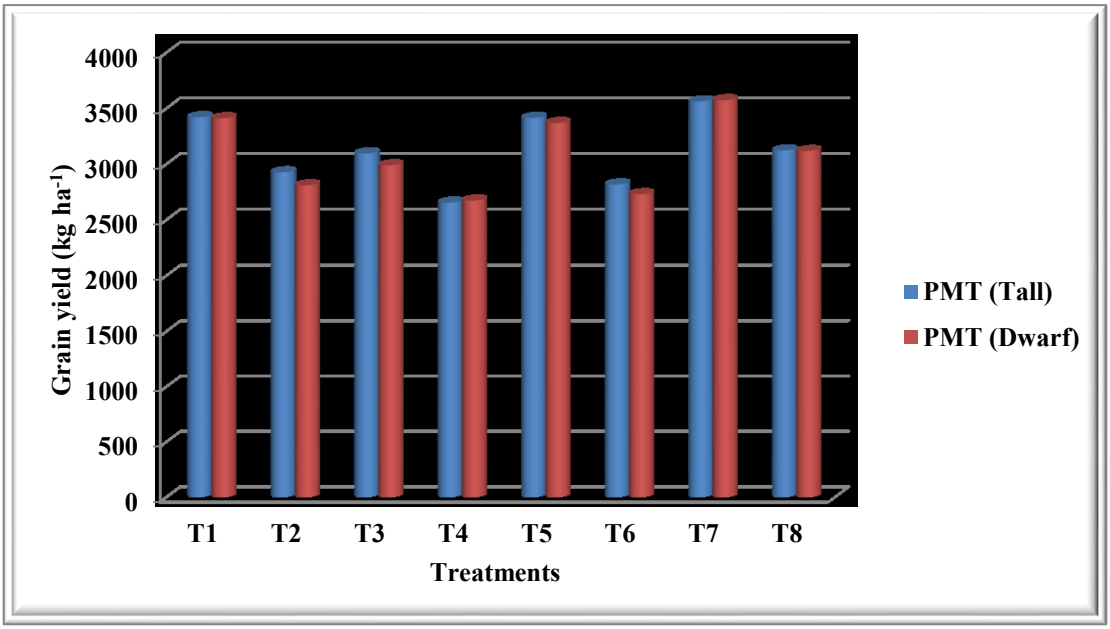


Figure 16. Effect of treatments on grain yield - (PMT- Tall) and (PMT- Dwarf)

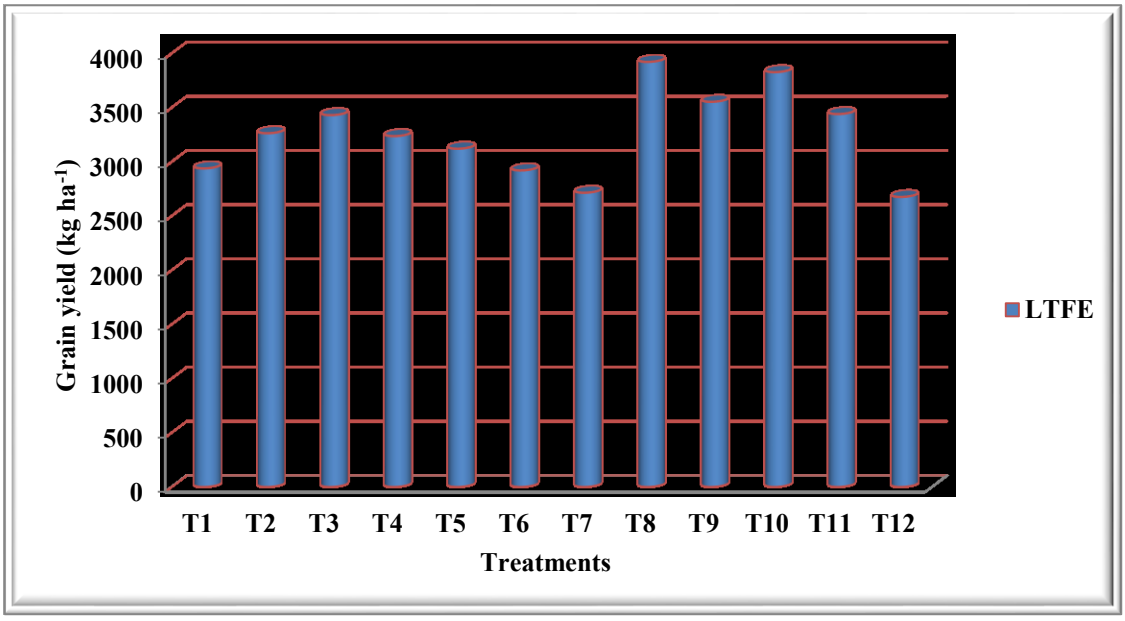


Figure 17. Effect of treatments on grain yield – LTFE

soil is alleviated by the addition of FYM through its nutrient supplying power and positive effect on physico - chemical and biological properties of soil, imparting a positive influence on yield characters as proposed by Ranjini (2002). Thus it is clear from the data that the observed increase in grain yield achieved is attributable to an increase in nutrient use efficiency, microbial activity and improvement in the physico-chemical characteristics of soil. Reddy *et al*. (1985) from studies on soil nutrient mineralization suggested the role of soil enzymes in the mineralisation of N, P, K and other nutrients in different cropping system. Kurumthottical (1982) based on permanent manurial trial with rice at ORARS, Kayamkulam reported that the highest grain yield was recorded from plots where N was applied as cattle manure alone and application of cattle manure alone or in combination with chemical fertilizers significantly increased the plant uptake of N, P and K. FYM when applied along with 100 per cent NPK as inorganic fertilizers solubilized native P and K in soil by the production of organic acids and enhanced their availability. According to Beena *et al*. (2002) application of cattle manure enhanced the biological activity in soil and influenced the mineralisation of organic carbon. The crop yields under integrated nutrient management and *in situ* green manuring were found to be on par.

5.10 STRAW YIELD

Straw yields of the experiments followed the same trend as their grain yields with respect to the treatment effects, the highest values being recorded by the treatment involving the combination of cattle manure, green manure and chemical fertilizers (Figure 18). The results are in agreement with Kavimani *et al*. (2000) who reported the application of FYM along with chemical fertilizers contributed N to rice besides leaving a substantial effect on succeeding crops. A combined use of organic manures and inorganic fertilizers is known to reduce N losses by forming organic mineral complexes and thus ensure continuous N availability to rice plants resulting in greater yield. Higher nutrient status obtained through chemical fertilizers and the sustained release of plant nutrients by the mineralisation of the applied organics account for the highest

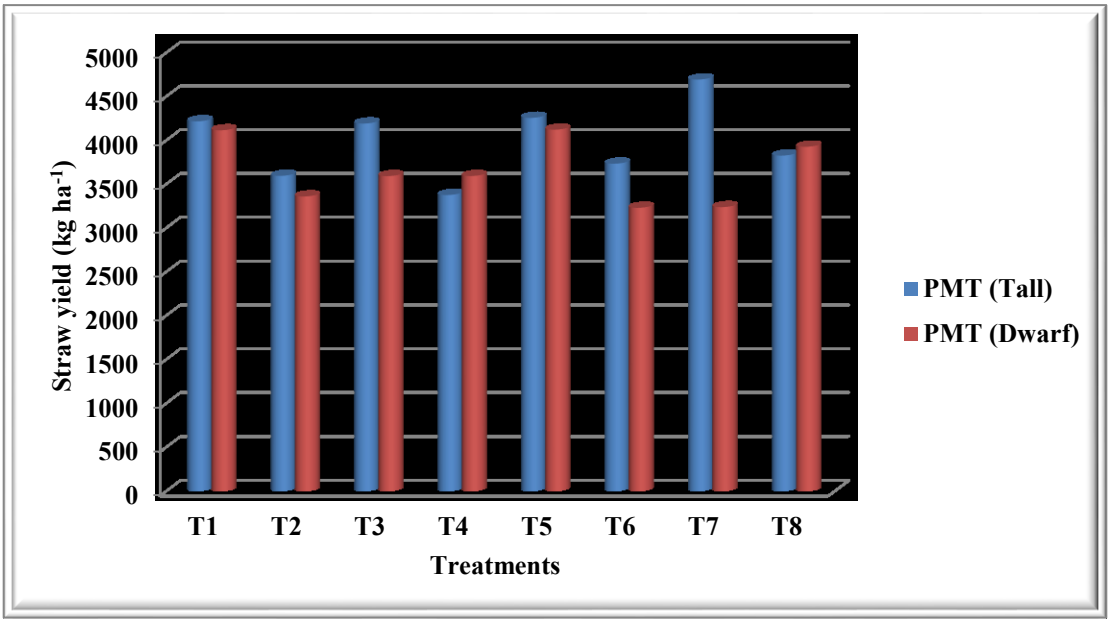


Figure 18. Effect of treatments on straw yield - (PMT- Tall) and (PMT- Dwarf)

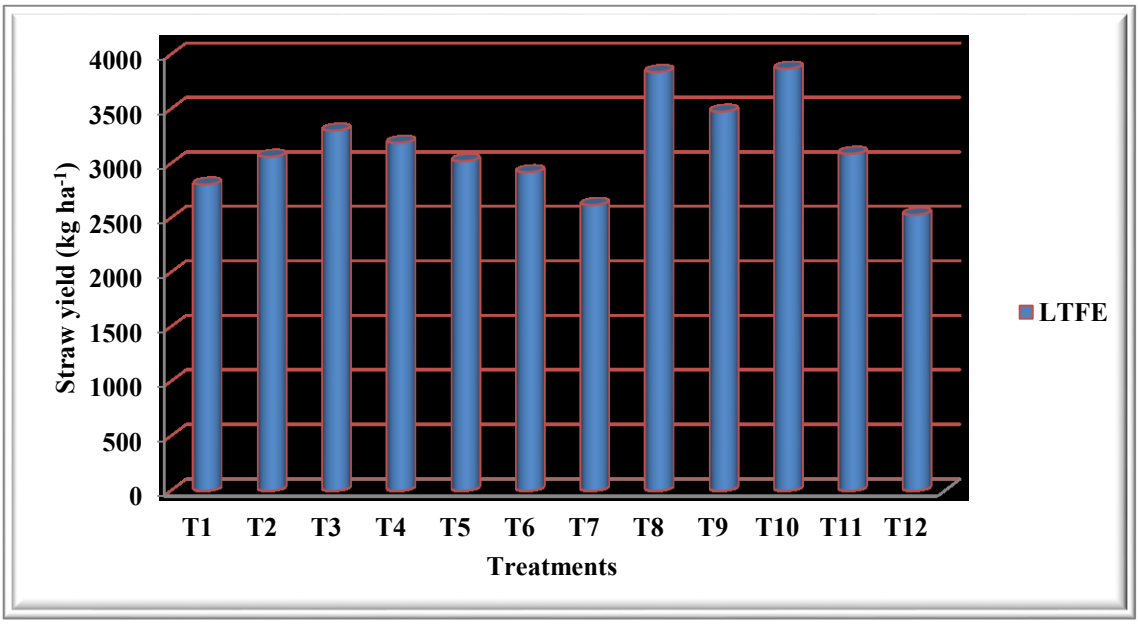


Figure 19. Effect of treatments on straw yield – LTFE

straw yields registered (Figure 19). Further the enhancement of microbial populations and their associated enzyme activity leading to improvement of soil environment might have also contributed to the increased straw yields. Further the integrated use of organic manures and chemical fertilizers has been found to be promising in arresting the decline in productivity through the correction of marginal deficiencies of some secondary and micronutrients.

Summary

6. SUMMARY

The experiment titled 'Biological profile of ferralitic alluvial paddy soils under long term differential fertilizer application' was carried out at Regional Agricultural Research Station, Pattambi and College of Agriculture, Vellayani to study the effect of long term application of organic manures, commercial fertilizers and their combinations on the biological properties of soil and in turn the growth and yield of rice of three long term fertilizer experiments such as Permanent Manurial Trial with Tall indica rice variety (PMT- Tall), Permanent Manurial Trial with Dwarf indica rice variety (PMT- Dwarf) and AICRP on long term fertilizer experiment (LTFE). The post harvest (Kharif, 2012-13) soil samples of the three experiments formed the study material for estimating their biological properties. Data on plant characters and yield collected from Regional Agricultural Research Station, Pattambi relate to Rabi crops (2012-13) of these experiments.

The findings which are generated out of detailed investigations carried out at laboratory, field levels and the subsequent statistical analysis are summarized below.

- Soil macrofauna include both earthworms and arthropods. Only for LTFE the earthworm count could be taken as the soil temperature of both the Permanent Manurial Trials were too high for their survival in the top soil layers. The treatments significantly influenced the arthropod population in both PMTs and earthworm and arthropod populations in LTFE.

  Treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) recorded the maximum earthworm count (16.25 $no.m^{-2}$) in LTFE.

  In (PMT- Tall) treatment T_5 (20 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest value of arthropods (73.00 no. kg^{-1} soil). In (PMT- Dwarf) treatment T_3 (45 kg N ha^{-1} as cattle manure + 45 kg N ha^{-1} as green manure) recorded the highest value (60.75 no. kg^{-1} soil) whereas, in LTFE the treatment T_8 (100 per cent NPK + FYM @ 5 t

ha^{-1} (to Kharif crop only)) recorded the highest arthropods count (78.00 no. kg^{-1} soil).

- The soil microflora populations of bacteria, fungi, actinomycetes, *Azospirillum, Azotobacter* and P solubilizers showed significant differences among different treatments in all the three experiments.

In case of (PMT- Tall) and (PMT- Dwarf) treatment combination with green manure, cattle manure and inorganic fertilizers T_7 recorded the maximum bacterial counts (81.75 and 86.50 x 10^6 cfu g^{-1} soil respectively). In LTFE treatment T_8 (100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) registered the highest bacterial population (61.50 x 10^6 cfu g^{-1} soil).

Regarding actinomycetes counts treatment T_7 with application of green manure, cattle manure and inorganic fertilizers recorded the highest values for both (PMT- Tall) and (PMT- Dwarf) (19.75 and 16.00 x 10^3 cfu g^{-1} respectively). Treatment T_8 with application of 100 percent NPK and FYM @ 5 t ha^{-1} recorded the highest actinomycetes population in LTFE (11.25 x 10^3 cfu g^{-1}).

Treatment T_7 (10 kg N ha^{-1} as green leaf + 10 kg N ha^{-1} as cattle manure + NPK @ 20:20:20 kg ha^{-1}) recorded the highest fungal count in (PMT- Tall) (57.00 x 10^4 cfu g^{-1} soil). Treatment T_6 with application of 45 Kg N ha^{-1} as green manure and NPK @ 45:45:45 kg ha^{-1} recorded the highest population (46.25 x 10^4 cfu g^{-1} soil) in (PMT- Dwarf) while in LTFE treatment T_8 (100 per cent NPK + FYM @ 5t ha^{-1} (to Kharif crop only)) recorded the highest number of fungi (48.50 x 10^4 cfu g^{-1} soil).

In case of *Azospirilium* count the treatment T_3 (20 kg N ha^{-1} as cattle manure + 20 kg N ha^{-1} as green leaf) recorded the highest count (64.25 x 10^4 cfu g^{-1} soil) in (PMT- Tall) and treatment T_6 with application of 45 kg N ha^{-1} as green manure and NPK @ 45:45:45 kg ha^{-1} recorded the highest (52.25 x 10^4 cfu g^{-1} soil) in (PMT- Dwarf) experiment. In LTFE

treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) recorded the highest population of *Azospirillum* (42.25 x 10^4 cfu g^{-1} soil).

Treatment 7 with combined application of green manure, cattle manure and inorganic fertilizers registered the highest populations of *Azotobacter* in both (PMT- Tall) and (PMT- Dwarf) (32.25 and 38.75 x 10^3 cfu g^{-1} soil respectively) whereas in LTFE treatment T_8 with application of 100 percent NPK and FYM @ 5t ha^{-1} recorded the highest *Azotobacter* count (28.25 x 10^3 cfu g^{-1} soil).

With respect to P solubilizer counts in both (PMT- Tall) and (PMT- Dwarf) treatment T_5 with application of N as cattle manure and NPK recorded the highest count (4.00 and 3.75 x 10^4 cfu g^{-1} soil respectively) while in LTFE treatment T_2 with application of 100 per cent NPK recorded the highest population (4.75 x 10^4 cfu g^{-1} soil).

- In soils of all the three experiments activities of the enzymes urease, phosphatase and dehydrogenase were significantly influenced by the different treatments.

In case of urease enzyme activity the highest values (363.68 and 406.24 µg urea g^{-1} soil hr^{-1} respectively) were recorded for the treatment T_7 with application of N as both green leaf and cattle manure + NPK for both (PMT- Tall) and (PMT- Dwarf) whereas in LTFE treatment T_8 with application of 100 percent NPK and FYM @ 5 t ha^{-1} recorded the highest urease activity (239.00 µg urea g^{-1} soil hr^{-1}).

Regarding the phosphatase enzyme activity treatment T_7 with application of N as both green leaf and cattle manure + NPK recorded the highest activity (44.83 µg p-nitrophenol g^{-1} soil hr^{-1}) in (PMT- Tall) whereas in (PMT- Dwarf) the highest value (39.15 µg p-nitrophenol g^{-1} soil hr^{-1}) was noticed for the treatment T_8 with application of NPK @ 90:45:45kg ha^{-1}. In LTFE treatment T_8 (100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)) recorded the highest phosphatase activity (39.15 µg p-nitrophenol g^{-1}soil hr^{-1}).

Dehydrogenase activity was found to be the highest in treatment T_7 with application of N as both green leaf and cattle manure + NPK for both (PMT- Tall) and (PMT- Dwarf) (527.17 and 496.99 µg TPF g^{-1}soil 24 hr^{-1} respectively) but in LTFE treatment T_8 with application of 100 percent NPK and FYM @ 5 t ha^{-1} recorded the highest activity of dehydrogenase (394.41 µg TPF g^{-1} soil 24 hr^{-1}).

- Other soil biological properties *viz.*, soil respiratory activity, microbial biomass carbon, C and N mineralisation potentials and hot water extractable carbohydrates were significantly influenced by the long term treatments.

In (PMT- Tall) treatment T_5 with application of 20 kg N ha^{-1} as cattle manure and NPK @ 20:20:20 kg ha^{-1} registered the highest respiratory activity (7.64 mg CO_2 100 g^{-1} soil d^{-1}) but in (PMT- Dwarf) treatment T_6 with N as green manure and NPK registered the highest activity (7.94 mg CO_2 100 g^{-1} soil d^{-1}). In LTFE treatment T_8 with application of 100 percent NPK and FYM @ 5 t ha^{-1} recorded the highest soil respiratory activity (7.03 mg CO_2 100 g^{-1} soil d^{-1}).

In case of microbial biomass carbon treatment T_7 with combination of green manure, organic manure and NPK application recorded maximum values in both (PMT- Tall) and (PMT- Dwarf) (499.95 and 569.43 µg g^{-1} soil respectively). Treatment T_8 with application of NPK and FYM recorded the highest microbial biomass C value (552.75 µg g^{-1} soil) in LTFE.

Regarding carbon mineralisation potential the highest value (1.75 per cent) was obtained in the case of treatment T_7 with green manure, organic manure and NPK application in (PMT- Tall) experiment whereas in (PMT- Dwarf), treatment T_1 with application of N as cattle manure alone (1.96 per cent) and in LTFE treatment T_8 with application of NPK and FYM recorded the highest carbon mineralisation potential (1.90 per cent).

Nitrogen mineralisation potential registered the highest value of (439.19 kg ha^{-1}) for treatment T_7 with application of N as both green leaf and cattle manure + NPK in (PMT- Tall). In (PMT- Dwarf) treatment T_3 with application of N as both cattle manure and green manure recorded the highest value (394.63 kg ha^{-1}) and in LTFE treatment T_{10} with NPK and *in situ* growing of *Sesbania aculeata* application recorded the highest nitrogen mineralisation potential (250.21 kg ha^{-1}).

Hot water extractable carbohydrates were found to be the highest in the case of treatment T_7 with application of N as both green leaf and cattle manure + NPK in both (PMT- Tall) and (PMT- Dwarf) (4940.90 and 5158.11 mg kg^{-1} soil respectively). In LTFE treatment T_8 with combination of NPK and FYM recorded the highest value (5917.08 mg kg^{-1} soil).

- Plant biometric characters *viz.* plant height, number of tillers $plant^{-1}$and number of panicle $plant^{-1}$, grain and straw yield also differed significantly between the treatments.

Treatment T_7 with combination of green manure, organic manure and NPK application registered the maximum values in (PMT- Tall) and (PMT-Dwarf) in the case of plant height (147.88 and 109.40 cm respectively), number of tillers $plant^{-1}$ (10.05 and 8.63 respectively) and number of panicles $plant^{-1}$ (9.93 and 8.33 respectively). In LTFE treatment T_{10} with NPK and *in situ* growing of *Sesbania aculeata* application recorded the highest plant height (107.63 cm) and number of tillers $plant^{-1}$ (11.30) and treatment T_8 with combination of NPK and FYM recorded the highest value of number of panicles $plant^{-1}$ (11.23).

Considering the yield of the experiments both grain and straw yields were the highest for the treatment T_7 with application of N as both green leaf and cattle manure + NPK (3563.25 and 4694.00 kg ha^{-1} respectively) but in (PMT-Dwarf) grain yield (3574.00 kg ha^{-1}) was the highest for treatment T_7 while the treatment T_5 with application of N as

cattle manure and NPK registered the highest straw yield (4122 kg ha^{-1}). In LTFE treatment T_8 with combination of NPK and FYM recorded the highest values for grain yield (3922.00 kg ha^{-1}) and treatment T_{10} with NPK and *in situ* growing of *Sesbania aculeata* application recorded the highest value for straw yield (3870.71 kg ha^{-1}).

- Soil characters like p^H, available P and K also were significantly influenced by different treatments.

Soil pH was found to be highest (5.95) in treatment T_5 with application of N as cattle manure and NPK in case of (PMT- Tall) whereas treatment T_2 with of N as green leaf alone application reported highest pH (5.89) in (PMT-Dwarf). In LTFE treatment T_4 with 100 per cent NPK + lime @ 600 kg ha^{-1}application recorded maximum pH value (5.75).

In (PMT- Tall) for both available P and K treatment T_7 with combination of green manure, organic manure and NPK application recorded maximum values (55.37 and 151.01 kg ha^{-1} respectively) whereas in (PMT-Dwarf) treatment T_7 was the highest for available P (61.13 kg ha^{-1}) and treatment T_6 with N as green manure and NPK application registered the highest available K content (143.50 kg ha^{-1}). In LTFE treatment T_8 with combination of NPK and FYM recorded the highest values for both available P and K content (21.29 and 97.79 kg ha^{-1} respectively).

- Simple correlations were worked out between the independent variable *viz.* biological property (X) and dependant variable, grain yield (Y) for at the three experiments.

Significant positive correlations exist for the grain yield of (PMT- Tall) with arthropod count (r = +0.462), bacterial count (r = 0.426), actinomycetes count (+ 0.355), fungal count (r = +0.613) and soil carbon mineralisation potential (+ 0.350) whereas in (PMT- Dwarf) grain yield has significant positive correlation with soil fungal count (r = +0.426),

Azotobacter count (r = +0.554), P solubilizers count (r = + 0.369), microbial biomass carbon (r = + 0.368) and nitrogen mineralisation potential of soil (r = +0.486). In LTFE yield was correlated positively and significantly with all the soil biological properties studied.

ASSESSMENT OF THE QUALITY/ HEALTH OF THE SOIL UNDER DIFFERENTIAL TREATMENTS OF THE PMTs AND LTFE USING SOIL BIOLOGICAL PROPERTIES AS EVALUATORY TOOLS.

The Permanent Manurial Trials and the AICRP on Long Term Fertility Experiment were initiated with the target of monitoring the yield responses of crops in the different agro ecological regions of the country under the impact of changes in soil environment due to continuous application of plant nutrient inputs through organic and inorganic sources. The conception and finalisation of the technical programme of the project have been done at the headquarters of the All India Co-ordinated Research Project at New Delhi and Regional Agricultural Research Station, Pattambi has been included ever since as a co-ordinating centre for the conduct of these experiments.

The present study was proposed with the objective of understanding the important biological properties of soils of RARS, Pattambi under long term fertilizer application as a result of continuous nutrient additions in organic, inorganic and combination forms. A critical glance at the technical programme of the Permanent Manurial Trials shows that a treatment serving as an absolute control *viz.* one without any manure or fertilizer is lacking for both the experiments. Added to this is the drawback of the lack of initial data on the biological properties of the soils under these experiments. So a proper judgement in terms of changes that the biological properties of the soil have undergone over the years due to continuous nutrient application cannot be strictly made. But for comparison purpose the biological properties of soils under treatment 7 (100 per cent NPK as per POP recommendation of KAU for the specific variety of rice in which 25 per cent N is applied as green manure and 25 per cent as cattle manure) as quantified by their discrete numerical values are compared against those of the soils under treatment 8 (100 per cent NPK as per POP, all as chemical fertilizers) for both experiments (Tables 25, 26). The choice of treatment 7 is based on its virtue as the highest yielder in addition to having the most favourable biological

properties while treatment 8 is the Package of practices recommendation of KAU for the respective rice variety.

In the case of AICRP on Long Term Fertility Experiment the comparison is between treatment 8 which is the best yielder as well as the one having the most favourable biological properties and treatment 12 which is the absolute control (Table 27).

The results clearly establish the role of integrated nutrient management in crop production not only for better crop yields, but also for sustainable soil health. The best treatments in all the three experiments were those which met the full recommendation of NPK requirement for the crops. For the Permanent Manurial Trials 50 per cent of the nitrogen requirement was supplied through organic sources, cattle manure and green leaf in equal splits. For LTFE, FYM @ 5 t ha^{-1} was supplied over and above the full NPK dose. More than playing their direct role in enhancing yield, the organic sources took care of the physical conditions of soil as well as soil secondary and micronutrient levels all leading to better soil physico-chemical-microbial interactions manifested as improved biological properties of soil and finally yield, the ultimate target of the farmer. If supplemented steadily with organic inputs the continuous use of inorganic fertilizers can build up soil organic carbon and improve its mineralisation potential as proved unequivocally from the results of this study.

FUTURE LINE OF WORK

For drawing valid conclusions on the effect of continuous application of nutrients in organic and inorganic forms each singly or in combination forms on the changes in soil environment and crop responses to them systematic and in depth studies are required on the following soil and crop aspects.

- Physical properties of soils
- Secondary and micronutrient levels in soil
- Direct, cumulative and residual effect of the organic inputs on soil
- Fractionation and characterisation of soil organic matter for each treatment

- Balance sheet of nutrients in soils
- Soil biological properties like microbial biomass N, P and S.
- Plant uptake of nutrients
- Seasonal effects

It is hoped that the findings and interpretations evolving from this study will help in planning better and judicious biological management strategies for these soils for sustainable health and crop production.

Table 25. A comparison of biological properties of Treatment 7 and Treatment 8 (PMT- Tall)

Sl. No.	Biological property	Treatment 7	Treatment 8	Increase (no. of times)
1	Arthropod population (no. kg^{-1} soil)	70.75	37.00	1.91
2	Bacterial population (x 10^6 cfu g^{-1} soil)	81.75	52.50	1.56
3	Actinomycetes population (x 10^3 cfu g^{-1} soil)	19	10	1.90
4	Fungal population (x 10^4 cfu g^{-1} soil)	57.00	34.00	1.68
5	*Azospirillum* population (x 10^4 cfu g^{-1} soil)	53.50	33.50	1.60
6	*Azotobacter* population (x 10^3 cfu g^{-1} soil)	32.25	13.00	2.48
7	P solubilizers population (x 10^4 cfu g^{-1} soil)	3.50	0.75	4.67
8	Urease activity (ppm urea g^{-1} soil hr^{-1})	363.68	273.03	1.33
9	Phosphatase activity (µg p-nitrophenol g^{-1} soil hr^{-1})	44.83	38.55	1.16
10	Dehydrogenase activity (µg TPF g^{-1} soil 24 hr^{-1})	527.17	205.11	2.57
11	Soil respiration (mg CO_2 100 g^{-1} soil d^{-1})	7.09	5.42	1.31
12	Microbial biomass carbon (µg g^{-1} soil)	499.95	217.97	2.30
13	Carbon mineralisation potential (%)	1.75	0.82	2.13
14	Nitrogen mineralisation potential (kg ha^{-1})	439.19	413.69	1.06
15	Hot water extractable soil carbohydrates (mg kg^{-1} soil)	4940.90	2483.25	1.99
	Yield (kg ha^{-1})	3563.25	3123.00	1.14

Table 26. A comparison of biological properties of Treatment 7 and Treatment 8 (PMT- Dwarf)

Sl. No.	Biological property	Treatment 7	Treatment 8	Increase (no. of times)
1	Arthropod population (no. kg^{-1} soil)	49.50	32.50	1.52
2	Bacterial population (x 10^6 cfu g^{-1} soil)	86.50	32.75	2.64
3	Actinomycetes population (x 10^3 cfu g^{-1} soil)	16.00	7.25	2.21
4	Fungal population (x 10^4 cfu g^{-1} soil)	43.50	24.00	1.81
5	*Azospirillum* population (x 10^4 cfu g^{-1} soil)	45.75	36.00	1.27
6	*Azotobacter* population (x 10^3 cfu g^{-1} soil)	38.75	19.25	2.01
7	P solubilizers population (x 10^4 cfu g^{-1} soil)	3.25	1.50	2.17
8	Urease activity (ppm urea g^{-1} soil hr^{-1})	406.24	228.22	1.78
9	Phosphatase activity (µg p-nitrophenol g^{-1} soil hr^{-1})	36.38	39.15	0.93
10	Dehydrogenase activity (µg TPF g^{-1} soil 24 hr^{-1})	496.99	202.55	2.45
11	Soil respiration (mg CO_2 100 g^{-1} soil d^{-1})	7.71	6.83	1.13
12	Microbial biomass carbon (µg g^{-1} soil)	569.43	267.67	2.13
13	Carbon mineralisation potential (%)	1.63	1.45	1.12
14	Nitrogen mineralisation potential (kg ha^{-1})	371.43	298.98	1.24
15	Hot water extractable soil carbohydrates (mg kg^{-1} soil)	5158.11	2119.84	2.43
	Yield (kg ha^{-1})	3574.00	3117.00	1.15

Table 27. A comparison of biological properties of Treatment 8 and Treatment 12 (LTFE)

Sl. No.	Biological property	Treatment 7	Treatment 8	Increase (no. of times)
1	Earthworm population (no. m^{-2})	16.25	7.00	2.32
2	Arthropod population (no. kg^{-1} soil)	78.00	40.50	1.93
3	Bacterial population (x 10^6 cfu g^{-1} soil)	61.50	24.00	2.56
4	Actinomycetes population (x 10^3 cfu g^{-1} soil)	11.25	2.50	4.5
5	Fungal population (x 10^4 cfu g^{-1} soil)	48.50	15.25	3.18
6	*Azospirillum* population (x 10^4 cfu g^{-1} soil)	42.25	15.50	2.73
7	*Azotobacter* population (x 10^3 cfu g^{-1} soil)	28.25	9.50	2.97
8	P solubilizers population (x 10^4 cfu g^{-1} soil)	4.25	0.25	17
9	Urease activity (ppm urea g^{-1} soil hr^{-1})	239.00	141.50	1.69
10	Phosphatase activity (µg p-nitrophenol g^{-1} soil hr^{-1})	38.54	17.63	2.19
11	Dehydrogenase activity (µg TPF g^{-1} soil 24 hr^{-1})	394.41	188.28	2.09
12	Soil respiration (mg CO_2 100 g^{-1} soil d^{-1})	7.03	3.63	1.94
13	Microbial biomass carbon (µg g^{-1} soil)	552.75	205.45	2.69
14	Carbon mineralisation potential (%)	1.90	1.32	1.44
15	Nitrogen mineralisation potential (kg ha^{-1})	228.83	177.27	1.29
16	Hot water extractable soil carbohydrates (mg kg^{-1} soil)	5917.08	2132.43	2.77
	Yield (kg ha^{-1})	3922.00	2676.00	1.47

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Biological Profile of Ferralitic Alluvial Paddy Soils Under Long Term Differential Fertilizer Application

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ABSTRACT

The present study on "Biological profile of ferralitic alluvial paddy soils under long term differential fertilizer application" was formulated with the objective of studying the variations in the important biological properties of ferralitic alluvial soils under long term fertilizer experiments with rice-rice cropping sequence and the relationship of these properties with yield and yield attributes. The soils of three long term fertilizer experiments at RARS, Pattambi (listed below) formed the study material 1) Permanent Manurial Trial with tall indica rice variety (PMT- Tall), 2) Permanent Manurial Trial with dwarf indica (PMT- Dwarf), 3) AICRP on long term fertilizer experiments (LTFE).

For (PMT- Tall) the treatment combination T_7 which is an integrated nutrient package of 10 kg N ha^{-1} as green leaf (GL) + 10 kg N ha^{-1} as cattle manure (CM) + NPK 20:20:20 kg ha^{-1} significantly and positively influenced most of the soil biological properties like bacteria, fungi, actinomycetes and *Azotobacter*, levels of soil enzymes urease, phosphatase and dehydrogenase, microbial biomass carbon (MBC), C and N mineralization potential, hot water extractable carbohydrates (HWC) and in turn plant characters like height, no. of tillers and no. of panicles $plant^{-1}$ and ultimately grain and straw yield. For other characters like population of arthropods, P solubilizers and soil respiration T_5 (20 kg N ha^{-1} as CM + NPK 20:20:20 kg ha^{-1}) and for *Azospirillum* count T_3 (20 kg N ha^{-1} as CM + 20 kg N ha^{-1} as GL) registered the maximum values. The same trend in favour of integrated nutrient management was observed for (PMT- Dwarf) also, T_7 (22.5 kg N ha^{-1} as GL + 22.5 kg N ha^{-1} as CM + NPK @ 45:45:45 kg ha^{-1}) registering significantly the highest values for properties like bacteria, actinomycetes, *Azotobacter*, soil enzymes, MBC, HWC, plant height, no.of tillers, no. of panicles $plant^{-1}$ and grain yield. For characters like fungi, *Azosprillum* population and respiratory activity T_6 (45 kg N ha^{-1} as GM+ NPK @ 45:45:45 kg ha^{-1}) was the most effective as was T_5 (45 kg N ha^{-1} as CM + NPK @

45:45:45 kg ha^{-1}) for P solubilizers and straw yield, T_3 (45 kg N ha^{-1} as CM + 45 kg N ha^{-1} as GM) for arthropod count and N mineralization and T_1 (90 kg N ha^{-1} as CM) for C mineralisation

In LTFE T_8, also an integrated nutrient package {100 percent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)} produced significantly the higher populations of earthworms, arthropods, bacteria, actinomycetes, fungi, *Azospirillum*, *Azotobacter*, soil enzymes, MBC, HWC, C and N minerlisation potential, no. of panicles and in turn grain yield. Only for a very few characters the other treatments had any effect like T_{10} {100 percent NPK + *in situ* growing of *Sesbania aculeata* (for Kharif crop only)} for straw yield and no. of tillers and T3 (150 percent NPK) for p solubilizers.

In nutshell for sustenance of soil health and maximum yield, treatment T_7 (10 kg N ha^{-1} as GL+ 10 kg N ha^{-1} as CM + NPK @ 20:20:20 kg ha^{-1}) can be adjudged to be the best for (PMT- Tall). For (PMT- Dwarfl), T_7 (22.5 kg N ha^{-1} as GL + 22.5 kg N ha^{-1} as CM + NPK @ 45:45:45 kg ha^{-1}) was the best treatment and T_8 {100 per cent NPK + FYM @ 5 t ha^{-1} (to Kharif crop only)} for LTFE.

Appendices

APPENDIX I

Weather Parameters during field experiment (September 2012- April 2013)

	Max. Temp	Min. Temp.	RH	Monthly Rf
September	30.6	23.7	94	220.2
October	32.4	23.7	92	234.9
November	32	22.3	93	74.6
December	33.2	21.7	85	6.2
January	34.3	20.7	85	0
February	35.1	22.7	81	79.5
March	36	24.1	86	55.2
April	38.7	25.5	84	0

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

4. Enumeration of Azospirillum

Media: Nitrogen free bromothymol blue

Composition

1. Mallic acid - 5g
2. K_2HPO_4 - 0.5g
3. $MgSO_4.7H_2O$ - 0.20g
4. NaCl - 0.10g
5. $CaCl_2$ - 0.02g
6. Trace element - 2ml
7. BTB - 2ml
8. $FeSO_4$ - pinch
9. Yeast extract - pinch
10. KOH - 40g
11. Agar - 32g
12. Distilled water - 1000ml

5. Enumeration of Azotobacter

Media: Jensen's Agar

Composition

1. Sucrose - 20g
2. K_2HPO_4 - 1g
3. $MgSO_4$ - 0.50g
4. NaCl - 0.50g
5. $FeSO_4$ - 0.10g
6. Na_2MoO_4 - 0.005g
7. $CaCO_3$ - 2g

8. Agar - 15g

9. Distilled water - 1000 ml

6. Enumeration of P- solubilizer

Media: Pikovaskaya's Agar

Composition

1. Glucose - 10g
2. $Ca_3 (PO_4)_2$ - 5g
3. $(NH_4)_2 SO_4$ - 0.5g
4. KCl - 2g
5. $MgSO_4$ - 0.10g
6. $MnSO_4$ - 0.10g
7. $FeSO_4$ - pinch
8. Yeast extract - 0.5g
9. Agar - 30g
10. Distilled water - 1000ml