BIOLOGICAL INDICATORS OF SOIL HEALTH AS INFLUENCED BY PLANT NUTRIENT SOURCES

by

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THESIS

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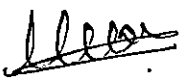
2013

DECLARATION

I hereby declare that this thesis entitled **"Biological indicators of soil health as influenced by plant nutrient sources "** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.



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Mekha M.G.

Dedicated to

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kg plant^{-1}	kilogram per plant
kg ha^{-1}	kilogram per hectare
m	Metre
mg	Milligram
ml	Millilitre
MOP	Muriate of potash
MSL	Mean Sea Level
µ g 100^{-1}	Microgram per 100 gram
N	Nitrogen
nm	nanometre
no.	number
org	Organic
P	Phosphorous
P_2O_5	Phosphate
Plant $^{-1}$	Per plant
POP	Package of Practices
ppm	parts per million
RP	Rock phosphate
SE	Stanaderd Error
s	seconds
t	tonnes
TPF	Triphenyl Formazone
TTC	Triphenyltetrazolium chloride
viz.	namely

LIST OF ABBREVIATIONS

%	percent
µg	microgram
^{0}C	Degrees Celsius
B:C	Benefit: Cost
BM	Bone meal
C	Carbon
CD	Critical difference
cm	centimetre
dS	deci Siemens
d	day
et al.	And others
Fig.	Figure
FYM	Farm Yard Manure
g	gram
g plant^{-1}	gram per plant
g plot^{-1}	gram per plot
h	hour
ha^{-1}	per hectare
i.e.	that is
K	Potassium
KAU	Kerala Agricultural University
kg	kilogram

kg plant^{-1}	kilogram per plant
kg ha^{-1}	kilogram per hectare
m	Metre
mg	Milligram
ml	Millilitre
MOP	Muriate of potash
MSL	Mean Sea Level
µ g 100^{-1}	Microgram per 100 gram
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Introduction

1. INTRODUCTION

Soil health, defined as the functional status of the different properties of a soil at a given time is the key element in sustainable agriculture, which aims at striking a balance between economic and environmental security to mankind. Ever since man became wise enough to recognize the finite nature and fragility of soil, its health has been a matter of growing concern to him. A healthy soil is defined as a stable system with high levels of biological diversity and activity, inherent nutrient cycling and resilience to disturbances (Rameshchandra and Singh, 2009)

Recent efforts to quantify soil health have resulted in the development of some evaluator tools which employ indicators, physical, chemical and biological to assess the impact of management on soil and environment. To quantify quality of soils a minimum data set composed of a number of carefully chosen soil physical, chemical and biological indicators are needed. These properties reflect the key dynamics properties of soil with regard to the spatial scale and time span. The parameters included in the minimum data set should be such that they are independent of each other. However in a mixed complex system like soil it cannot be expected that every factor will be independent of each other.

Soil biological indicators which respond to changes in soil quality have been suggested as more sustainable and hence better indicators of soil health than physical and chemical soil properties which alter only after a drastic change in soil quality. Soil biological attributes are early warners of soil degradation and are good indicators for comparing the relative performance of different soil management practices. For India the minimum data set prescribed for assessing soil health are microbial biomass, soil respiration and soil enzymes (Ramesh *et al.*, 2004)

The relationship between various crop management practices and soil biological properties is well recognized, though not well understood. Among the

management practices, fertilizer application has the most direct link with biological properties as the soil biota is largely determined by the type, form and quantity of nutrients added to the soil.Though fertilizer application of inorganic fertilizers is the quickest and surest way of providing plant nutrient for obtaining higher crop yield the drastic pH drop following the use of acidogenic fertilizers may have detrimental effect on the microbial communities and thereby on all the soil biological properties centred around them. Organic manures, on the other hand are ideal, but their scarcity and over requirement limit their use.

Against this background the present study was planned and proposed with the objective of studying the changes the major biological properties of a soil undergo when the nutrient requirements of a crop grown on this are met by organic and inorganic sources. For the purpose of comparison and for arriving at confirmatory and conclusive inferences two soil types of Vellayani viz red loam and lateritic were included on each of which amaranthus was raised as the test crop. It is hoped that the results will help not only in planning a judicious manurial schedule for the crop for obtaining high yield without jeopardizing soil health but will also throw light on the comparative dynamics of soil biological properties under organic and inorganic plant nutrition, so that they can be employed as reliable and useful tools for evaluating soil health.

Review of Literature

2. REVIEW OF LITERATURE

The present study is an attempt to compare the effect of the forms of the three major plant nutrients N, P and K on the biological properties of two types of Vellayani soils viz. red loam and lateritic when applied to amaranth crop grown on these soils. The nutrients were supplied through organic as well as inorganic sources. The effect of treatments on the growth, yield characters and quality of crop were also studied. A review relevant to the present investigation with emphasis on biological properties of soils is presented in this chapter.

2.1 PLANT CHARACTERS

2.1.1 Growth characters

Singh and Sitaramaiah (1963) reported increased plant height in bhindi due to oil cake application. Chinnaswamy (1967) observed better growth in tomato plants with the application of FYM and groundnut cake in organic mixtures.

Application of FYM resulted in higher plant height, vegetative mass, dry weight and rate of dry matter increment per unit leaf area of capsicum (Valsikova and Ivanic, 1982). They also reported that application of chemical fertilizers in the absence of FYM retarded the formation of vegetative organs and subsequently the reproductive organs and resulted in lower flower production

Som *et al.* (1992) while studying the comparative influence of organic manures and inorganic fertilizers on growth and yield in brinjal found that maximum fruit length and diameter were recorded when mahua cake and neem cake were applied @ 50 q ha^{-1} respectively. Neemcake applied @ 50 q ha^{-1} produced the maximum fruit weight of 125.38 g, the highest per plant yield of 1.43 kg and the highest fruit yield of 22.56 t ha^{-1}

Application of basalt and glacial dust in lettuce, apple and sweet corn increased the soil fertility and plant growth in several soils of USA (Barker *et al.*, 1998). Yarrow (1998) reported that the application of rock dust as inorganic source of several plant nutrients increased the plant height and earliness of flowering in tomato.

Sharu (2000) reported that in chilli growth characters like plant height, number of branches and dry matter accumulation as a result of neem cake application were found to be on par with that of the POP recommendation of KAU

From pot experiments, Varaprasad *et al.* (2005) concluded that application of neem cake to tomato and castor cake to aubergine at 5.0 g kg^{-1} of soil was the most effective in the enhancement of plant growth parameters (shoot height, shoot weight, root weight and root volume). Growth characters like number of branches $plant^{-1}$ and plant spread showed significant variation in coleus due to application of rock dust @ 10 t ha^{-1} mixed with equal quantity of FYM.(Divya, 2008).

2.1.2 Yield attributes and yield

Increase in the yield of okra by organic manure application was reported by Gaur *et al.* (1984). Islam and Haque (1992) considered oil cake as a good organic manure to be applied during land preparation of brinjal, chilli and bhindi for getting higher yield.

From trials on the effects of organic and inorganic amendments on soil physical properties and maize production in a severely degraded sandy soil Obi and Ebo (1995) reported that application of organic waste alone and in combination with mineral fertilizer enhanced root and shoot biomass, general growth and yield components of crops compared to sole application of NPK fertilizer.

Roe *et al.* (1997) studied the performance of green pepper and cucumber in a sandy soil fertilized with compost or mineral fertilizers. They found that yields were usually higher when compost was combined with mineral fertilizers.

Investigations on the effect of organic and mineral fertilizers on growth, yield and composition of pepper (*Capsicum annum* L.) by Aliyu (2000) showed that application of poultry manure at 5t ha^{-1} and FYM at 5-10t ha^{-1}supplemented with 50kgNha^{-1} resulted in adequate crop growth and maximum fruit yield of pepper.

Arunkumar (2000) observed that in amaranthus application of neemcake produced higher yield as compared to that of chemical fertilizers on equivalent N basis, but was inferior to that of FYM, vermicompost and poultry manure.

Based on trial conducted to study the effects of starter fertilizers on the growth and N use efficiency of onion and lettuce, Stone (2000) reported that ammonium phosphate fertilizer applied early as a starter fertilizer improved early growth and final yields compared to broadcast NH_4NO_3.

From studies on the effect of N forms on growth and nitrate accumulation in onion Inal *et al.* (2001) reported that the fresh and dry weight were greater with NO_3^- as the N source compared with NH_4^+ or urea.

Raj and Geetha Kumari (2001) observed that application of FYM along with neem cake and Azospirillum each at 150kg ha^{-1} recorded the highest fruit yield and profit in bhindi.

Meerabai *et al.* (2003) reported that in chilli substitution of recommended N with organic manures like neem cake, poultry manure or green manures like cowpea or glyricidia gave comparable yields and net returns as that of POP recommendation of KAU.

In South-West Nigeria, Owolabi *et al.* (2003) found that the application of wood ash from sawdust alone significantly increased yield of tomato and okra and their leaf nutrient contents.

Xu *et al.* (2005) in a study on yield and quality of leafy vegetables grown with organic fertilizers showed that vegetables grown with organic fertilizers grew better and resulted in a higher total yield than those grown with chemical fertilizers.

Asha (2006) found that in amaranthus the highest yield of 15.07 t ha^{-1} was recorded in neem cake applied plots compared to enriched compost. Pradhan *et al.* (2010) reported a significantly higher root biomass production in red beet (*Beta vulgaris* L.) fertilized with urine and ash compared to mineral fertilizers

From studies on plant characteristics and yield of kohlabi as affected by different organic manures Uddin *et al.* (2009) reported that the plants which had been fertilized with chicken manure had the highest growth parameters and marketable yield.

Based on detailed investigations of the effects of organic fertilizers on growth, yield, quality and sensory evaluation of red lettuce Michael *et al.* (2010) reported that type of fertilizer applied significantly affected growth, yield and nutritional quality of lettuce. A trend in superiority of the different types of organic fertilizers was observed as the chicken manure exhibited relatively higher values on number of leaves, plant height, marketable yield and mean leaf dry mass.

From studies on the influence of pongamia, mahua and neem cakes on finger millet productivity and soil fertility Shivakumar *et al.* (2011) revealed that application of recommended FYM along with neem cake equivalent to 100 per cent recommended N performed better in respect of productivity and maintenance of soil fertility followed by recommended FYM with 100 per cent NPK through fertilizers.

2.1.3 Quality characters

Kansal *et al.* (1981) opined that application of organic manure in the form of 20 t FYM ha^{-1} increased the ascorbic acid content in spinach leaves. Montagu and Ghosh (1990) found that fruit color of tomato significantly increased as a result of application of organic manures of animal origin.

Abusaleha (1992) recommended equal or more quantity organic form of N than inorganic N for getting good quality okra fruits.

From a study on nitrate content in vegetable crops as affected by soil characteristics, rate and type of fertilization, Gianquinto *et al.* (1992) reported that application of FYM alone reduced nitrate accumulation in lettuce. According to Anitha (1997) chilli plants treated with poultry manure recorded the maximum ascorbic acid content of fruit as compared to vermicompost and control treatments.

Organic manures like FYM, compost, oil cake, green leaf, poultry manure etc. improve the yield as well as quality of vegetable crops like tomato, onion, gourds, chilli etc. Increase of ascorbic acid content in tomato, pyruvic acid in onion and minerals in gourds are the impact of application of organic manure to vegetable crops (Rani *et al.*, 1997).

Saharawat and Mukherjee (1997) reported that application of mahua cake improved the grain protein content in rice. Joseph (1998) observed that in snake guard, poultry manure treated plant recorded the highest crude protein and the lowest crude fibre content as compared to FYM and vermicompost treated plants.

Arunkumar (2000) reported that in amaranthus maximum protein content was obtained with poultry manure application as compared to that with FYM, vermicompost, coir pith compost and POP recommendation. From studies on recycling of organic materials Huang and Lin (2001)found that the application of organic manures combined with chemical fertilizers improved the quality of crops.

Bhadoria *et al.* (2002) found that protein and total mineral content of okra fruit were high, when it was grown with FYM. Nair (2003) reported that quality attributes like ascorbic acid content and iron content were highest when chemical fertilizer was substituted with poultry manure. Omae *et al.* (2003) observed that cattle compost application increased freshness and vitamin C content in melon.

Sheeba (2004) showed that the treatments with organic sources of plant nutrients recorded the highest values for beta carotene content, protein content and the lowest fiber and oxalates content in amaranthus.

2.2 SOIL CHARACTERS (SOIL BIOLOGICAL INDICATORS)

2.2.1 Soil megafauna

2.2:1.1 Earthworm population

Scullion and Ramshaw (1987) studied effects of various manurial treatments on earthworm activity in grassland and reported that poultry manure application increased population of earthworms. From studies on functional implications of soil fauna diversity in boreal forests Huhta *et al.* (1998) found no earthworms in control soils and only a few in ash treated soil.

From studies on the effect of wood ash on earthworm abundance Lundkvist (1998) found an increased abundance of earthworms in wood ash treated soil. Reganold and Palmer (1995) used earthworm population per square metre, total earthworm weight and average worm weight as biological indicators of soil health. Ten earthworms per square feet of soil surface can be considered as a good population in agricultural system.

Vestberg *et al.*(2009) studied the effects of cropping history on the quality of a silt soil cropped with strawberries and reported that farming system affected earthworms positively by increasing their numbers from 64.9 earthworms m^{-2} soil in conventional to 134.9 in organic. From studies on earthworm abundance and species composition in organic forage production system Hurisso *et al.* (2011)

reported 5.4 times increase in earthworm population by the application of composted dairy manure.

2.2.1.2 Micro arthropods

Nakamura (1976) found that the microarthropod decomposer community temporarily increased after cow dung application, Patino and Fernandez (1978) found more micropores in a soil manured with straw than in an unmanured soil and this supported higher abundance of soil microarthropods in the organically manured soil. Curry (1994) reported that moderate applications of cattle and pig slurry resulted in moderate increases of hemiedaphic Collembola.

Huhta *et al.* (1998) observed a decrease in the total abundance of microarthropods following forest wood ash fertilization during their studies on the functional implications of soil fauna diversity in boreal forests.

Scholte and Lootsma (1998) studied the effect of FYM and green manure crops on populations of mycophagous soil fauna and reported that FYM had a stimulative effect on microarthropods. From studies on Collembola and mites in plots fertilized with different types of green manure Axelsen and Kristensen (2000) reported that the input of organic matter in various forms, such as green manures and crop residues, increased populations of microarthropods.

From studies on the responses of soil fauna to wood-ash fertilisation and burning in a coniferous forest stand Haimi *et al.* (2000) observed that wood ash fertilization decreased the total population of microathropods. Miyazawa *et al.*(2002) investigations on the effect of cropping system and fallow management on microarthropod populations and concluded that application of organic matter increased the number of microarthropods by supplying various nutrients, enhancing plant growth, and altering soil conditions

Sjursen *et al.*(2005) studied effects of long-term fertilisation on microarthropod abundances in three sub-arctic ecosystems and reported that inorganic fertilization increased population of microathropods.

Evaluation of root effect on soil organisms under different fertilization was investigated by Eo and Nakamoto (2007) who reported higher population densities of microarthropods in the inorganically fertilized plots which appeared to be linked to higher microbial activities.

2.2.2 Soil microflora

Based on a study on the effect of ash fertilization upon the microbes of some swamps Huikari (1953) reported that wood ash application increased the amounts of aerobic bacteria and yeasts in the surface layer of peat, but decreased the amounts of moulds.

Schalin (1967) studied the effect of N fertilization on the bacterial and microfungi population in humus layer and found that fungi increased after urea fertilization as long as the pH did not exceed 4.3, above which bacteria increased. Karsisto (1979) conducted studies on the effect of ash fertilization in soils and observed an increase in the total number of bacteria 53 years after wood ash treatment.

Based on trials on the effect of wood ash and NPK fertilizers on microbial activities in a histosol by Weber *et al.* (1985) showed that there was an increase in the number of aerobic, amylolytic, denitrifying and clostridial bacteria 2 years after wood ash treatment. Wood ash application is assumed to influence soil microbial processes either directly (Baath and Arnebrant, 1994) or indirectly by inducing an increase in soil pH and changes in the elemental composition of the soil environment (Killham, 1994).

Baath *et al.* (1995) observed a change in humus layer microbial community structure two years after wood ash fertilization. From results of long term studies on soil microbial and biochemical properties for ten years with urea and anhydrous ammonia Biederbeck *et al.* (1996) reported that fungal and bacterial populations were positively related to N rate and were greater in soil treated with anhydrous ammonia than in urea-treated soil.

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. Selvi *et al.* (2004) in a study on microbial population and biomass in rhizhosphere as influenced by continuous intensive cultivation and fertilization in an Inceptisol recorded the highest bacterial and actinomycetes counts at the end of the crop with the addition of FYM along with 100 per cent NPK.

From studies on the impact of organic farming on biological properties of rice Krishanakumar *et al.* (2005) reported that the populations of soil bacteria, fungi and actinomycetes significantly increased following the application of the organic N sources compared to control. Among the organic N sources, FYM + neem cake resulted in the highest population densities of bacteria (38.6×10^{-6} cfu g^{-1}soil), fungi (15.2×10^{-6} cfu g^{-1}soil) and actinomycete (12.2×10^{-4} cfu g^{-1}soil).

Solomon *et al.*, (2008) based on his studies on effect of neem extract on soil properties and microbial populations reported that neem seed cake increased population of *Arthrobacter.* From investigations on the impact of neem seed cake on soil microflora and some soil properties Elnasikh *et al.* (2011) revealed that neem seed cake positively affected the population of actinomycetes and negetatively the population of fungi.

From a trial on the effect of integrated nutrient management on yield and microbial population in sodic soil, Bahadur *et al.* (2012) reported a significant increase in bacterial population under conjoint use of inorganic fertilizers with organic manure and dual inoculation of biofertilizers.

2.2.3 Soil enzymes

Studies relating to the effect of soil properties on the level of urease activity have indicated that the activity tends to increase with organic matter content (Silva and Perera, 1971).

Kiss *et al.* (1975) suggested that enzymes that accumulate in the soil have biological significance as they participate in the cycling of elements and thus play a very important role in the initial phase of the decomposition of organic residues. According to Skujins (1976) the level of enzyme activity can be used as an indicator of soil fertility.

Burns (1982) proposed that soil enzyme activity can be used for evaluating soil fertility and suggested the measurement of four activities namely urease, phosphatase, invertase and catalase as reliable indicators.

Soil enzymes play an important role in the mineralization processes and also many other soil biological reactions (Tate, 1987).Studies on the effect of systematic fertilizer application and manuring on biological processes in soil revealed that fertilization increased the microbial proliferation and also the enzyme activites (Ampova and Parishkova, 1983).

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 dehydrogenase activity and soil respiration thus indicating a high microbial population.

Haider *et al.*(1991) observed an increased C: N ratio due to the application of cow dung along with oil cake, resulting from an increased microbial biomass C and activity of urease and dehydrogenase enzymes. Addition of organic residues increased the activities of amylase, aryl sulphatase, catalase, deaminase, dehydrogenase and phosphomonoesterase enzymes (Perucci, 1992).

Joseph and Prasad (1993) found that neem cake coated urea inhibited the activity of urease by reducing the hydrolysis of urea derived NH_4.

Studies on the effect of compost addition by Martin and Marinissen (1993) revealed that the activity of dehydrogenase increased to a peak of 2101 microgram TPF 24 hr^{-1} with the application of vermicompost.

Clarholm and Brinck (1995) observed an increase in acid phosphatase activity two year after wood ash application.

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) from 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.

According to Cooper and Warman (1997) application of compost showed an increased activity of dehydrogenase in a silty clay soil than the application of other manures or fertilizers. Application of chicken manure compost significantly increased the phosphatase activity in a low organic matter silty clay soil but had no effect on a sandy loam soil.

Bergstrom *et al.* (1998) suggested that dehydrogenase activity is a respiratory measurement and hence is a more strong representative of the size and activity of viable microbial community than the activity of other soil enzymes, which exist in viable cells and as enzymes stabilized in soil matrix. Pauscal (1998) also reported that the application organic amendments in arid soil increased dehydrogenase activity.

Rogar *et al.* (1998) observed that the activity of the alkaline phosphatase enzyme increased due to the application of compost compared to the application of ammonium nitrate alone or unfertilized. Tateno (1998) observed increased activity of dehydrogenase due to the application of poultry manure in a clay loam soil.

In a long term study on enzyme activities at the soil- litter interface of a loamy sand Kandler *et al.* (1999) found that application of NPK fertilizers with FYM increased enzyme activities.

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

From studies on the effect of wood ash on soil respiration and microbial properties in an acid forest soil Zimmermann and Frey (2002) reported that acid and alkaline phosphatase activities declined immediately after the wood ash application where as the enzyme activities of the N cycle were stimulated .

A pot culture experiment and laboratory incubation studies were carried out to evaluate the addition of different organic manures on soil urease activity using rice as test crop. Among the organic manures, FYM @10 t ha^{-1} recorded significantly higher urease activity as compared to poultry manure, paddy straw and green manures. Urease activity also increased up to 60 days and there after decreased in the soils incubated with different organic manures (Srinivas et al., 2004).

Studies on the influence of organics and various levels of NPK on the soil enzyme activity in a costal sandy Typic Udipsamment revealed that the combined application of coir pith compost @12.5 t ha^{-1} and 150 per cent NPK increased phosphatase,urease and dehydrogenase activities (Elayaraja and Singaravel ,2011)

2.2.4 Soil respiration

From studies on the effects of ash on biological activities in two contrasting soils Raison and Mc Garity (1980) observed that ash addition to soil (sandy podzolic soil) increased the respiration rate (measured as CO_2 production), compared to a sterilized control soil.

Based on investigations on the growth rate and response of bacterial communities to pH in limed and ash treated forest soils Baath and Arnebrant (1994) detected an increased CO_2 evolution in the mineral layer four years after wood ash treatment.

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 fish meal increased in general bacteria by 160 per cent, *Azotobacter* by 246 per cent, fungi by 236 per cent and CO_2-production by 194 per cent.

Fritze et al. (2000) found in a two month experiment in which 5 t ha^{-1} of wood ash was applied to coniferous forest humus, a 1.5 fold increase in basal respiration. Thirukkumaran and Parkinson (2000) found that application of N as inorganic salts in silvicultural practices often suppresses microbial respiration and biomass in forest soils.

From studies on the effect of wood ash on soil respiration and microbial properties in an acid forest soil Zimmermann and Frey (2002) reported that wood ash amendment resulted in a rapid change in the rate of CO_2 evolution, Manna *et al.* (2005) studied the long term effect of fertilizer and manure application soil quality, organic C storage and crop yield of some sub humid tropical soils and reported that application of N alone or with P led to decline in organic C, soil respiration and microbial biomass C and N which improved with addition of N, P, K or NPK+ FYM.

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.

2.2.5 C mineralization potential

From microplot experiments conducted in an Entisol Mukherjee *et al.* (1995) reported that application of mustard cake increased soil organic C content after 60 days.

Hakeem *et al.* (2007) reported that organic C in the surface soil layer was significantaly more in neem treated plots as compared to control.

From studies on nutrient mineralization from deoiled neem seed in a savanna soil Agbenin *et al.* (2008) reported that neem-amended soil maintained organic C at the pre-incubation level, whereas that in the control soil declined to significantly less than the pre-incubation concentration.

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

From studies on integrated nutrient management in coconut Basavaraju and Hanumanthappa (2010) reported that application of neemcake + bonemeal + ash increased the organic C status of a red sandy loam soil.

From studies on mineralization dynamics and biochemical properties following application of organic residues to soil Zsolnay (1996) reported that the dynamics and amount of mineralized C were affected by the nature of chemical constituents of residues.

Studies on the influence of organics and various levels of NPK on the soil nutrient availability in a coastal sandy typic Udipsamment revealed that application of coirpith compost @12.5 t ha^{-1} registered the highest organic C status followed by the application of poultry manure @12.5t ha^{-1}(Elayaraja and Singaravel 2011).

Patra *et al.* (2011) reported that addition FYM@ 10 t ha^{-1} significantly increased organic C content of a sandy loam soil followed by the combined application of vermicompost, phosphocompost, poultry manure and neem cake each at 2.5t ha^{-1}.

2.2.6 N mineralization potential

Shivananda (1986) carried out a laboratory study to find out the rate of N mineralization in soils amended with castor cake, FYM, maize straw and paddy straw. Among these castor cake was mineralized rapidly and it released high amounts

of NH_4-N and NO_3-N. An increase in available N content of soil up to 20 days after FYM application and a decrease there after was noticed in a long-term field experiment with wheat (Gupta *et al.*, 1988).

From trials on some aspects of chemical changes as influenced by different organic additives in an Entisol of Gangetic origin Mukherjee et al. (1995) reported that neem cake application increased the total N. From results of an incubation study Hulagur (1996) reported that the amount of mineralized N from neem cake increased up to seven days after incubation. Recovery of mineral N from neem cake diminished at 14th day of incubation and thereafter there was gradual increase.

Sharu (2000) reported that highest application level of poultry manure (5 t ha^{-1}) recorded the highest level of soil N compared to vermicompost, neem cake and POP recommendation in chilli. Hakeem *et al.* (2007) reported that *Rhizobium* inoculation in conjugation with neem cake @300 ha^{-1} recorded significant increase in available N in soil at crop harvest relative to initial status.

Based on studies on nutrient mineralization from deoiled neem seed in a savanna soil Agbenin et al. (2008) reported that the concentrations of NH_4-N and nitrate N mineralized from the neem-amended soil were two to three times greater than the control.

From a study on mineralization dynamics and biochemical properties following application of organic residues to soil Mondini et al. (2010) reported that animal by-products caused a significant increase in the content of mineral N and water soulable soluble C and N, while plant residues produced immobilization of mineral N.

Wood ash application can significantly affect N mineralisation process by altering the activity and changing the composition and population of soil microbes through changes in soil chemical properties (Saarsalmi *et al.*, 2010).

Rosenberg *et al.* (2010) reported that application of wood-ash would increase both C and N mineralisation rates in a N-rich soil whereas the net N mineralisation rates would not be affected in a N-poor soil.

Zsolnay (1996) studied the effect of different organic sources on the mineralization dynamics and biochemical properties of soils and reported that animal by-products caused a significant increase in the content of net extractable mineral N ranging from 13 to 33 per cent of the N added indicating an increase in the mineral N available for plant.

Patra *et al.* (2011) reported that combined application of vermicompost, Phosphocompost, poultry manure and neem cake each at 2.5t ha $^{-1}$increased the available N content of a sandy loam soil. Studies on the influence of organics and various levels of NPK on the soil nutrient availability in a coastal sandy typic Udipsamment showed that application of coirpith compost @12.5 t ha^{-1} along with 150% NPK fertilizer increased N availibilty (Elayaraja and Singaravel 2011).

Saha *et al.* (2012) studied the effect of neem cake and N on the yield and uptake of nutrients by wheat and reported that available N, P and organic C content of post-harvest soil samples increased with the increasing levels of N and neem cake application.

Materials and Methods

3. MATERIALS AND METHODS

Detailed investigations involving laboratory studies and two field experiments were carried out at College of Agriculutre, Vellayani on the changes the major biological properties of soils undergo when the nutrient requirements of crops on these are met by organic and inorganic sources. For the purpose of comparison and for arriving at confirmatory and conclusive inferences two soil types of Vellayani viz red loam and lateritic were selected on each of which amaranthus was raised as the test crop.

The details regarding field experiments conducted observations recorded, laboratory analytical methods followed and statistical techniques adopted for arriving at helpful inferences are discussed in this chapter.

3.1. DETAILS OF FIELD EXPERIMENTS

Two separate field experiments were carried out at two locations in the Instructional farm of College of Agriculture, Vellayani. Geographically the area is located at 8° 5' N latitude and 77° 1' E longitude and at an altitude of 29 m above MSL.

3.1.1 Experimental sites

The field experiment in the red loam soil type was carried out in the Block E of the Instructional Farm, Vellayani where as the experiment in lateritic soil type was carried out in the D Block. From both locations soil samples were collected and analysed for the basic physic- chemical biological parameters as per standard procedures given in Table 1.

Table. 1. Analytical methods adopted for soil initial analysis

Sl. No	Parameter	Method	Reference
1	Mechanical analysis	International pipette method	Piper, 1967
2	pH	pH meter	Jackson,1973
3	EC	Conductivity meter	Jackson,1973
4	CEC	Neutral normal ammonium acetate method	Jackson,1973
5	Organic carbon	Walkley and Black rapid titration method	Walkley and Black, 1934
6	Available N	Alkaline permanganate method	Subbiah and Asija, 1956
7	Available P	Bray No. 1 extraction and photoelectric colorimetry	Jackson,1973
8	Available K	Neutral normal ammonium acetate and flame photometry	Jackson,1973
9	Earthworm count	Visual observation method	
9	Arthropodes	Berlese- Tullgreen funnel method	Macfayden, 1961
10	Soil microflora	Serial dilution method	Timonin, 1940
11	Urease	Para dimethyl amino benzaldehyde method	Broadbent *et al.*, 1964.
12	Phosphatase	Para nitrophenyl phosphate method	Eivazi and Tabatabai 1977
13	Dehydrogenase	Triphenyl tetrazolium choride method.	Cassida *et.al* 1964
14	Soil respiration	CO_2 evolution method	Jenkinson and Powlson ,1976

3.1.2 Design and lay out of the experiment

The study being a comparison of the effects of different nutrient sources on the biological properties of soil under a crop of amranthus, the treatments were combinations of different nutrient sources to supply the recommended NPK requirements of the crop viz 50:50: 50 kg ha $^{-1}$ (KAU POP, 2011). The following common technical programme was adopted at both locations.

Design : Randomized Block Design

Crop & Variety: Amaranth var. Arun

Spacing :30x20 cm

Plot size: 1.5x1.5 m

Replications : 3

Treatments

N sources 1. Urea

2. Oil cake(neem)

P sources 1. Rock phosphate

2. Bone meal

K source 1.Muriate of potash

2. Wood ash

Treatment No.	Treatment combinations	Treatment notaions adopted
T_1	Urea+Rock phosphate+Muriate of potash (KAU POP, 2011)	Urea+ RP+ MOP
T_2	Urea+Rock phosphate+Wood ash	Urea+RP+ WA
T_3	Urea+Bone meal+Muriate of potash	Urea+BM+MOP
T_4	Urea+Bonemeal+Wood ash	Urea+BM+WA
T_5	Oil cake+Rock phosphate+Muriate of potash	OC+RP+MOP
T_6	Oil cake+Rock phosphate+Wood ash	OC+RP+WA
T_7	Oil cake+Bone meal+Muriate of potash	OC+BM+MOP
T_8	Oil cake+Bone meal+ Wood ash	OC+BM+WA
T_9	KAU Organic POP(2009)	KAU Org POP
T_{10}	Control (No manure, No fertilizer)	Control

FYM@10t ha^{-1} was applied to all treatments except T_{10}

All the inputs except wood ash were purchased locally from Koliyoor Co-operative society. Wood ash was procured from the student's canteen attached

to College of Agriculture, Vellayani. The nutrient compositions of the above inputs were analysed adopting standard procedures as outlined in Table 2.

The layout of the experiments are presented in Fig. 1(red loam soil) and Fig. 2 (lateritic soil).

Over view of the experimental sites are presented in Plate1.a (red loam soil) and plate 1.b. (lateritic soil)

3.1.3 Crop and variety

Arun, a high yielding purple hued multi cut photo insensitive variety of amaranthus developed through mass selection from 'Palappor local' by Kerala Agricultural University was used.

3.1.4 Season

Both crops were raised simultaneously from May to June , 2012. Weather parameters during the cropping season were recorded from the meteorological observatory of the College of Agriculture, Vellayani and are presented as fortnightly averages in Appendix 1 and graphically in Fig. 3.

3.1.5 Planting material

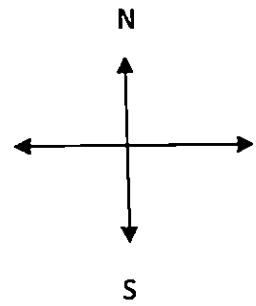
Seeds of amaranthus variety Arun were purchaced from the Instructional Farm, Vellayani.

3.1.6 Nursery details

Amaranthus seedlings were raised in four wide earthen pots, two filled with well prepared red loam soil and two with lateritic soil. A basal dressing of powdered cattle manure @ 1 kg m^{-2} was applied in the nursery soil and the seeds were sown. The seedlings were given light irrigation and handweeding was done as per requirement.

Plate1.a General view of the experiment site- Red loam soil

Plate1.b General view of the experiment site - Lateritic soil



T_1	T_6	T_3	T_7	T_9	T_5	T_8	T_4	T_{10}	T_2
T_5	T_1	T_{10}	T_8	T_6	T_2	T_9	T_7	T_4	T_3
T_{10}	T_4	T_6	T_3	T_2	T_7	T_5	T_8	T_1	T_9

Fig. 1. Lay out of the field experiment - Red loam soil

T_2	T_3	T_9
T_{10}	T_4	T_1
T_4	T_7	T_8
T_8	T_9	T_5
T_5	T_2	T_7
T_9	T_6	T_2
T_7	T_8	T_3
T_3	T_{10}	T_6
T_6	T_1	T_4
T_1	T_5	T_{10}

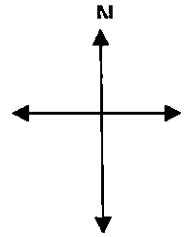


Fig. 2. Layout of the field experiment- Lateritic soil

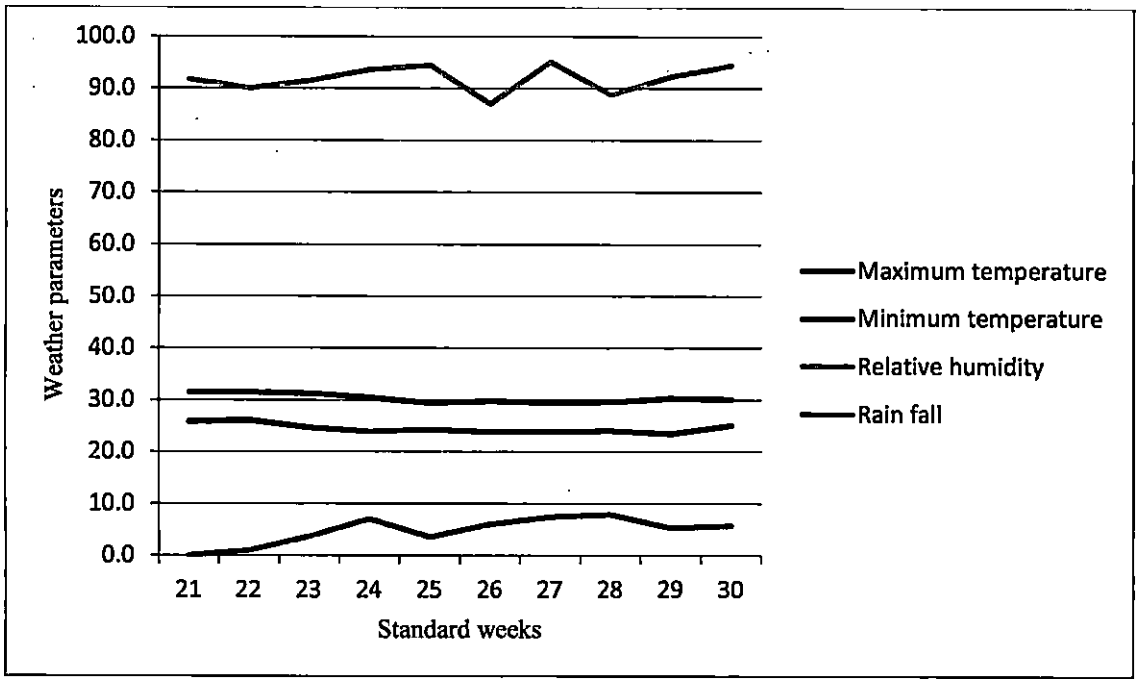


Fig. 3. Weather parameters during field experiments (May 2012 to July 2012)

3.1.7 Main field preparation

At both locations the fields were prepared by ploughing followed by levelling. Thiry plots were formed at each location in which trenches were made 30cm apart. Well rotten FYM @50t ha^{-1} was applied and mixed with soil in all treatment plots except T_{10}.

3.1.8. Transplanting

Twenty five day old seedlings were transplanted in the main fields at a distance of 20cm between plants in the trenches and provided with shade, taking care to see that seedlings raised on red loam nursery were planted in red loam main field and lateritic soil nursery were planted in lateritic main field.

3.1.9 Manures and fertilizers

Neem oil cake (4.56 per cent N), bone meal (18.50 per cent P_2O_5) and wood ash (8.30 per cent K_2O) were used as organic sources of N, P and K and urea (46 per cent N), rock phosphate (20 per cent P_2O_5), and muriate of potash (58 per cent K_2O) were used as inorganic sources of N, P and K respectively. The nutrient sources were applied as per technical programme to the plots. Half N, full P and half N were applied one week after transplanting when the seedlings gained establishment in the main field. The rest of N and K were applied 20 days after the basal application.

3.1.10 After cultivation

Gap filling was done to have plants at the recommended spacing, regular irrigation and weeding were also carried out.

Table 2. Analytical method adopted for input analysis

Sl. No	Parameter	Method	Reference
1	Oil cake	Digestion in H_2SO_4 and microkjeldhal distillation	Jackson,1973
2	Bonemeal	Nitric – perchloric (9:4) digestion and colorimetry	Jackson,1973
3	Ash	Nitric – perchloric (9:4) digestion and flame photometry	Jackson,1973
4	Urea	Digestion in H_2SO_4 and microkjeldhal distillation	FCO, 1998
5	Rock Phospahte	Volumetric ammonium phospho molybdate method.	FCO, 1998
6	MOP	Perchoric acid method	FCO, 1998

3.1.11 Plant protection

As there was no incidence of any major pest or disease no plant protection measures were adopted.

3.1.12 Harvesting

The first harvest in both fields were done 25 days after transplanting, subsequent harvests were done at two days interval and completed with in one week after the first harvest.

3.2. PLANT CHARACTERS

The following important growth characters of plant were recorded on the last day prior to harvest at both sites. For taking observations five plants in each plot were randomly selected and the mean worked out for each character studied.

3.2.1 Growth characters

3.2.1.1 Height of the plant (cm)

The height of the plant was measured from the base at ground level to the growing tip.

3.2.1.2 Girth of stem (cm)

The girth of the plant was measured at 10cm height from the ground level.

3.2.1.3 Number of branches plant $^{-1}$

The total number of branches arising from the main stem were counted.

3.2.1.4 Number of leaves plant $^{-1}$

The total number of leaves of the plant were counted.

3.2.1.5 Root length (cm)

The plant was uprooted and its root length was measured from base of the stem to the tip of the main root.

3.2.1.6 Root volume (ml)

Root volume was measured as the volume of water displaced by the root when it was immersed in a measuring cylinder containing known volume of water.

3.2.2 Yield attributes and yield

The following yield characters of the crop were recorded after harvest of the crop. Five randomly selected plants were used for this and average value for each trait computed.

3.2.2.1 Shoot biomass plant^{-1} (g)

The entire plant was uprooted and separated into shoot and root portions by cutting the main stem at the junction of the above ground and below ground portions. The above ground mass of the plant was weighed as the shoot biomass.

3.2.2.2 Root biomass plant^{-1} (g)

The entire root portion of the plant was cut made free of adhering soil and other particles by washing in running water, wiped dry and weighed.

3.2.2.3 Total biomass plant^{-1} (g)

Total biomass of the plant was calculated by summing up the weight of the shoot biomass and root biomass.

3..2.2.4 Leaf weight plant^{-1} (g)

The entire leaves from a plant were separated and the weight recored.

3.2.2.5 Stem weight plant^{-1} (g)

The weight of the shoot excluding the leaves was recorded.

3.2.2.6 Leaf stem ratio plant^{-1} (g)

The leaf stem ratio was worked out as the ratio between leaf weight and stem weight of a plant.

3.2.2.7 Total yield plot^{-1}

The mature plants in a plot were harvested by cutting each plant at ground level. The harvested plants were pooled together and weighed .The weight of plants harvested at the different cut stages were summed up to get the total yield plot^{-1}.

3.2.3 Quality parameters

The shoot portion of the harvested plants were chopped and pooled and homogenous samples were drawn for analysis. The pre weighed samples were oven dried at 70 ^{0} C and their final weights recorded to calculate the per cent moisture content. They were ground in Wiley mill and used for the estimation of those quality parameters for which dry samples were required. For others fresh plant samples were used.

3.2.3.1 Vitamin C

Vitamin C content of fresh leaves was estimated by 2, 6- dichlorophenol indophenol dye method (Sadasivam and Manickam, 1996) and expressed in mg 100 g $^{-1}$ fresh sample.

3.2.3.2 Crude Protein

Dry plant samples were used for the estimation of N content by microkjeldal digestion in H_2SO_4 followed by distillation (Jackson ,1973).The protein content was calculated by multiplying the per cent N content with the factor 6.25 (Simpson, 1965).

3.2.3.3 Beta carotene

Beta carotene content of fresh leaves was estimated by the method proposed by Srivastava and Kumar (1998) and expressed as μg 100 g^{-1} fresh sample.

3.2.3.4 Nitrate content

Nitrate content in the dried plant samples was estimated by the method proposed by Middleton (1958) and expressed as per cent of dry weight.

3.2.3.5 Oxalate content

The oxalate content was estimated by the method proposed by AOAC (1984) in dried plant samples and expressed as per cent of dry weight.

3.3 SOIL CHARACTERS (SOIL BIOLOGICAL INDICATORS)

As all the soil characters studied are related to the biological activities in the soil fresh rhizosphere soil samples were used for the analysis for the following biological properties of the soil.

3.3.1 Soil mega fauna

3.3.1.1 ***Earthworm population (no. m^{-2} soil)***

Immediately after harvest of the plants the top soil in a m^{-2} area of land in each plot was dug and spread on a sheet of paper. The number of earthworm in this was counted.

3.3.1.2 *Micro arthropods (no. kg $^{-1}$ soil)*

Micro arthropods like collembola and mites were counted using Berlese-Tullgreen funnel method. (Macfayden,1961).The illutration of the same is given as Plate 2.

3.3.2 Soil microflora (cfu g^{-1} soil)

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

Soil bacteria- Nutrient agar medium

Soil actinomycetes- Kenknight's medium

Soil fungi- Martins rose bengal streptomycin agar medium

3.3.3 Soil Enzymes

3.3.3.1 *Urease activity* (µg NH_4^+-N g^{-1}soil 24 h^{-1})

The urease activity was determined by following the method described by Broadbent *et al,* (1964). To 20 g soil weighed into an Erlenmayer flask, 4 ml of urea substrate solutioun was added. Enough water was added to each flask to maintain a tension of 1/3 bar and incubated for 24 hours at 30 ^{0}C. Then the flasks were removed and $CaSO_4$ solution was added to make up the volume to 100ml. About 15 ml of the supernatant was taken and colour was developed by adding 10 ml of para-dimethyl amino benzaldehyde which was then read in a Spectrophotometer at a wavelenghth of 420 nm. Standards were also prepared by using urea solutions of known concentrations.

3.3.3.2 *Phosphatase activity* (µg of p- nitrophenyl g^{-1} of soil hr^{-1})

The phosphatase activity was determined by following a procedure described by Eivazi and Tabatabai (1977).To 1 g soil in a 50 ml Erlen Meyer flask, 0.2ml toluene, 4ml modified universal buffer (pH-6.5) and 1ml p-nitrophenol phosphate solution were added and incubated at 23^{0}C for one hour. After incubation, 0.5 ml $CaCl_2$ (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

Plate 2. Method used for the estimation of soil micro arthropod

wavelenghth of 420 nm. One percent of p-nitrophenyl phosphate was used for the preparation of standards.

3.3.3.3 *Dehydrogenase Activity(μg TPF g^{-1} soil 24 h^{-1})*

Dehydrogenase activity was estimated as per the procedure described by Cassida *et.al* 1964. 60g of the 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 hrs at 27°C. After incubation, the soil was quantitavely 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.

3.3.4 Soil respiration

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

3.3.5 Carbon mineralization potential

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

3.3.6 Nitrogen mineralization potential

Nitrogen mineralization potential of soils was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956).

3.4 ECONOMIC ANALYSIS

The benefit cost ratios of both crops were calculated separately by working out the respective total costs of outputs and inputs and taking the ratios between them.

3.5 STATISTICAL ANALYSIS

The data generated out of the field observations and subsequent laboratory analysis were scrutinized using the technique of Analysis of variance applicable to Randomised Block Design described by Cochran and Cox (1965).

Results

4. RESULTS

Investigations were carried out at College of Agriculture, Vellayani to study the changes the major biological properties of a soil undergo when the major nutrients to a crop grown on it are supplied organically or inorganically or in their different combinations. The investigations consisted of laboratory studies and two field trials with Amaranthus var. Arun (May to July, 2012) in two soil types of Vellayani, red loam and lateritic.The salient results generated out of these studies are presented and briefly discussed in this chapter.

4.1 BASIC PROFILE OF THE SOILS AT THE EXPERIMENTAL SITES

Important physical, chemical and biological properties of the two soils selected for study are presented in Table 3.

The red loam soil was acidic in reaction (pH 5.50), very low in electrical conductivity (0.17 d S m^{-1}), low in cation exchange capacity (3.59 cmol (p+) kg^{-1}), organic C (0.41 per cent), available N (244.60 kg ha^{-1}) and available K (114.89 kg ha^{-1}), but high in available P (41.43 kg ha^{-1}). Texturally the soil was sandy clay loam with the taxonomic position Loamy Kaolinitic Isohperthermic Rhodic Kandiustult.

The lateritic soil was also acidic in reaction (pH 5.80), very low in electrical conductivity (0.18 d S m^{-1}) , low in cation exchange capacity (3.20 cmol (p+) kg^{-1}), organic C (0.45 per cent), available N (188.16 kg ha^{-1}) , high in available P (48.16 kg ha^{-1}) and medium in available K (125.89 kg ha^{-1}). Texturally the soil was sandy clay loam with the taxonomic position Loamy Skeletal Kaolinitic Isohperthermic Typic Kandiustult.

Table 3. Important physical , chemical and biological properties of soil at the experimental sites

Sl .No	Parameter	Content	
		Red loam Soil	Lateritic Soil
A.	**Physical properties**		
1.	Mechanical Composition		
	Sand	63.09	67.80
	Silt	10.08	7.90
	Clay	26.53	25.30
2.	Texture	Sandy clay loam	Sandy clay loam
B.	**Chemical properties**		
	1.pH	5.50	5.80
	2.EC dSm^{-1}	0.17	0.18
	3.CEC (cmol (p+) kg^{-1})	3.59	3.20
	4.Organic Carbon(%)	0.41	0.45
	5. Available N (kg ha^{-1})	244.60	188.16
	6. Available P (kg ha^{-1})	41.43	48.16
	7.Available K (kg ha^{-1})	114.89	125.89
C.	**Biological properties**		
1.	Soil mega fauna		
	a. Earthworms (no.m^{-2} soil)	0	0
	b. Arthropods (no. Kg^{-1} soil)	16.00	32.00

Table. 3. (continued) Important physical , chemical and biological properties of soil at the experimental sites

Sl. No	Parameters	Content	
		Red loam soil	Lateritic soil
2	Soil microflora		
	a. Bacteria (cfu g^{-1}soil)	16.00×10^4	23.00×10^4
	b. Fungi (cfu g^{-1}soil)	3.26×10^4	6.46×10^4
	c. Actinomycetes(cfu g^{-1}soil)	0	1.33×10^4
3.	Soil enzymes		
	a.Urease ($\mu g\ NH_4^+$-N g^{-1}soil d^{-1})	62.54	65.67
	b. Phosphatase (μg P-nitrophenol g^{-1} soil h^{-1})	60.30	52.53
	c. Dehydrogenase (μg TPF g^{-1} 24 h^{-1})	76.70	82.32
4.	Soil respiration (mg CO_2 100 g^{-1} d^{-1})	2.87	3.96

Table 4 Effect of treatments on height of plant and girth of stem

Treatments	Height of plant (cm)		Girth of stem (cm)	
	Red loam	Lateritic	Red loam	Lateritic
T_1	48.88	77.66	4.50	4.60
T_2	46.70	77.20	4.01	4.82
T_3	64.60	99.10	4.41	4.56
T_4	60.50	73.43	3.28	3.99
T_5	62.40	53.20	4.36	3.39
T_6	49.80	62.20	2.23	3.90
T_7	40.67	60.45	2.86	3.55
T_8	36.60	67.46	2.23	4.15
T_9	56.60	62.13	3.30	3.48
T_{10}	16.00	23.26	0.73	1.22
SE	2.59	3.93	0.36	0.31
CD (0.05)	7.707	11.691	1.062	0.923

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

Both soils were devoid of earthworm inhabitation at time of start of the experiments. Arthropods numbered 16 in a kilogram of the red loam soil where as it was 32 in a kilogram of the lateritic soil. Bacterial population was 16×10^4 cfu, fungi population 3.26×10^4cfu and actinomycetes 0 in a gram of red loam soil while the corresponding values for these in the lateritic soil were 23×10^4cfu, 6.46×10^4cfu and 1.33×10^4cfu respectively. Initial assay of the soils for enzyme activities showed a value of 62.54 µg NH_4^+-N g^{-1}soil d^{-1} for uresae,60.30 µg P-nitrophneol g^{-1} soil h^{-1} for phosphatase and 76.70 µg TPF g^{-1} 24 h^{-1} for dehydrogenase in the red loam soil. The corresponding values for these in the lateritic soil were 65.67 µg NH_4^+-N g^{-1}soil d^{-1} for uresae, 52.53 µg P-nitrophneol g^{-1} soil $h^{-1}$for phosphatase and 82.32 µg TPF g^{-1} 24 h^{-1} for dehydrogenase. Soil respiratory activity in red loam soil was 2.87 mg CO_2 100 g^{-1} d^{-1} as against 3.96 mg CO_2 100 g^{-1} d^{-1} in lateritic soil.

4.2 FIELD EXPERIMENTS

4.2.1. Effect of treatments on plant characters

4.2.1.1 Growth characters

4.2.1.1.1 Height of plant (Table 4)

Analysis of data revealed that plant height was significantly influenced by different treatments in both soils. The treatment combination (T_3) (Urea+ BM+MOP) recorded the maximum values for this character in both the soils, 64.60 cm in red loam soil and 99.10 cm in lateritic soil. T_3 was found to be on par with T_5(OC+ RP + MOP) (62.40 cm) and T_4 (Urea+BM+WA) (60.50 cm) in red loam soil. The lowest value for plant height was 16.00 cm noticed in T_{10} (control).

In lateritic soil T_3 was superior to all other treatments. T_1(Urea+ RP+MOP) (77.66 cm), T_2(Urea+RP+WA) (77.20 cm), T_4 (Urea+BM+WA) (73.43 cm) and T_8(OC+BM+WA) (67.46 cm) which followed T_3 were statistically on par. The treatment T_{10} (control) recorded the lowest value of 23.26 cm.

4.2.1.1.2 Girth of stem (Table 4)

Stem girth of plant was significantly influenced by different treatments in both soils. In red loam soil the treatment T_1 (Urea+ RP+MOP) recorded the highest mean value for stem girth of 4.50 cm and was closely followed by T_3. The lowest mean value of 0.73 cm was reported by the treatment T_{10}. The treatment T_1 was on par with T_3 (Urea+ BM+MOP) (4.41 cm),T_5 (OC+ RP + MOP) (4.36 cm) and T_2 (Urea+RP+WA) (4.01 cm).

In lateritic soil the treatment T_2 (Urea+RP+WA) recorded the highest mean value for stem girth of 4.82 cm and the lowest mean value of 1.22 cm was reported by the treatment T_{10}. The treatment T_2 was on par with T_1 (Urea+ RP+MOP) (4.60 cm),T_3 (Urea+ BM+MOP) (4.56 cm) and T_8(OC+BM+WA) (4.15 cm).

4.2.1.1.3 Number of branches plant $^{-1}$ (Table 5)

Table 5 presents the mean number of branches plant $^{-1}$. The data revealed that the treatments caused significant variation in number of branches plant $^{-1}$ in both soils. In red loam soil the highest mean value of 9.67 was registered by the treatment T_3(Urea+ BM+MOP) which was on par with T_9(KAU Org POP) (8.66) and T_6 (OC + RP +WA) (8.33). The treatment T_{10} (control) registered the lowest mean value of 2.33 plant $^{-1}$.

In lateritic soil the treatment T_8 (OC+BM+WA) registered the highest mean value of 9.00 and it was found to be on par with T_3(Urea+ BM+MOP). (8.67) and T_6 (OC + RP +WA) (8.00) and the lowest mean value for number of branches was recorded by the treatment T_{10}(control), which registered a mean value of 3.00.

Table 5 Effect of treatments on no. of branches plant $^{-1}$ and no. of leaves plant $^{-1}$

Treatments	No .of branches plant $^{-1}$		No .of leaves plant $^{-1}$	
	Red loam	Lateritic	Red loam	Lateritic
T_1	6.67	3.67	51.00	45.00
T_2	4.00	6.00	15.67	44.00
T_3	9.67	8.67	64.33	41.33
T_4	6.67	5.34	58.00	21.00
T_5	5.33	6.67	51.00	29.00
T_6	8.33	8.00	39.33	24.00
T_7	7.66	6.33	42.33	18.00
T_8	8.00	9.00	88.00	43.00
T_9	8.66	4.67	67.00	30.66
T_{10}	2.33	3.00	19.00	17.00
SE	0.49	0.76	3.49	2.59
CD (0.05)	1.471	2.282	10.363	7.701

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

4.2.1.1.4 Number of leaves plant^{-1} (Table 5)

Table 5 presents the number of leaves plant^{-1}. It was observed that there was significant difference in the number of leaves due to treatments. In red loam soil the highest mean value of 88.00 was recorded by the treatment T_8 (OC+BM+WA) and was significantly superior to all other treatments. The treatment T_2(Urea+RP+WA) recorded the lowest value of 15.67 and was on par with control T_{10}.

In lateritic soil the highest mean value of 45.00 was registered by the treatment T_1 (Urea+ RP+MOP) which was found to be on par with T_2 (Urea+RP+WA) (44.00), T_8(OC+BM+WA) (43.00)and T_3 (Urea+ BM+MOP) (41.33). The treatment T_{10} which registered a mean value of 17.00 was the lowest.

4.1.1.1.5 Root length (Table 6)

The data presented in Table 6 shows the effect of different treatment on root length of amaranthus. The treatments caused significant variation in root length. In red loam soil T_4 (Urea+BM+WA) recorded the maximum root length of 23.06 cm and it was found to be on par with T_1 (Urea+ RP+MOP) (22.53 cm), T_8 (OC+BM+WA) (21.16 cm), T_3 (Urea+ BM+MOP) (18.50 cm) and T_9 (KAU Org POP) (18.00 cm).The treatment T_6 (OC+ RP + MOP) recorded lowest the root length of 9.97 cm

In lateritic soil T_2 (Urea+RP+WA) recorded maximum root length of 17.60 cm and it was found to be on par with T_1 (Urea+ RP+MOP) (14.67 cm) and T_7 (OC+BM +MOP) (14.00) cm. The treatment T_{10} (control) recorded the lowest value of 10.5cm.

4.2.1.1.6 Root volume (Table 6)

The data given in Table 6 reveal that treatments significantly influenced root volume of the plants in both soils. In red loam soil the highest mean value of

Table 6 Effect of treatments on root length and root volume plant^{-1}

Treatments	Root Length (cm)		Root volume (ml)	
	Red loam	Lateritic	Red loam	Lateritic
T_1	22.53	14.67	15.00	19.00
T_2	15.06	17.60	7.33	10.67
T_3	18.50	12.33	17.33	6.33
T_4	23.06	11.93	7.33	6.67
T_5	13.10	13.33	14.66	7.33
T_6	9.97	13.16	5.00	6.00
T_7	16.67	14.00	10.00	8.33
T_8	21.16	12.66	21.33	10.33
T_9	18.00	13.77	13.33	5.33
T_{10}	15.37	10.50	4.67	3.67
SE	1.77	1.29	2.51	0.95
CD (0.05)	5.267	3.841	7.460	2.820

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

21.33 ml was recorded by treatment T_8 (OC+BM+WA) and was found to be on par with T_3 (Urea+ BM+MOP) (17.33 ml),T_1 (Urea+ RP+MOP) (15.00 ml) and T_5 (OC+ RP + MOP) (14.66 ml). The lowest value of root volume was noticed in T_{10} and it was 4.67 ml.

In lateritic soil the highest mean value for root volume, 19.00 ml was recorded by the treatment T_1 (Urea+ RP+MOP) which was significantly superior to all other treatments. It was followed by T_2 (10.67 ml), T_8(OC+BM+WA) (10.33 ml), T_7 (OC+BM +MOP) (8.33 ml) and T_5 (OC+ RP + MOP) (7.33 ml). They were statistically on par. The lowest value of root volume was noticed in T_{10} (control) and it was 3.67 ml.

4.2.1.2 Yield and yield attributes

4.2.1.2.1 Leaf weight plant^{-1} (Table 7)

Statistical analysis of the data revealed that treatments significantly influenced leaf weight plant^{-1} in both soils. In red loam soil T_1 (Urea+ RP+MOP) registered the highest per plant leaf weight of 69.18 g and was significantly superior to all other treatments. The treatment T_{10} (control) recorded the lowest value of 4.50 g plant $^{-1}$.

In lateritic soil also T_1 (Urea+ RP+MOP) registered the highest leaf weight of 57.53 g plant $^{-1}$ and was significantly superior to all other treatments. The treatment T_{10} registered the lowest mean value of 8.12 g plant $^{-1}$.

4.2.1.2.2 Stem weight plant^{-1}(Table 7)

The data summarized in Table 7 shows the significant influence of treatments on stem weight of Amaranthus. In red loam soil the highest per plant stem weight was recorded in T_1 (Urea+ RP+MOP) (74.86 g plant $^{-1}$) and was on par with T_3. The lowest stem weight was recorded in T_{10} (5.22 g plant $^{-1}$).

Table. 7. Effect of treatments on leaf weight plant $^{-1}$, stem weight plant $^{-1}$ and leaf stem ratio

Treatments	Leaf weight plant $^{-1}$ (g)		Stem weight plant $^{-1}$ (g)		Leaf stem ratio	
	Red loam	Lateritic	Red loam	Lateritic	Red loam	Lateritic
T_1	69.18	57.53	74.86	107.76	0.89	0.52
T_2	14.38	30.94	24.18	56.65	0.59	0.57
T_3	55.55	24.52	73.57	35.24	0.86	0.69
T_4	51.61	19.90	50.08	44.69	1.04	0.45
T_5	35.13	20.07	55.84	35.03	0.62	0.57
T_6	21.02	26.48	31.99	43.51	0.66	0.60
T_7	15.99	29.54	20.41	54.04	0.79	0.54
T_8	32.38	34.22	32.74	68.16	0.99	0.50
T_9	50.12	19.71	59.50	29.69	0.84	0.66
T_{10}	4.50	8.12	5.22	8.35	0.88	0.96
SE	4.46	2.75	3.84	5.30	0.06	0.04
CD(0.05)	13.262	8.161	11.390	15.751	0.203	0.142

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

In lateritic soil also the highest mean value of 107.76 g plant $^{-1}$was recorded by the treatment T_1 (Urea+ RP+MOP) and was significantly superior to all other treatments.The treatment T_{10} recorded the lowest value of 8.35 g plant $^{-1}$.

4.2.1.2.3 Leaf stem ratio (Table 7)

Effect of treatments on leaf stem ratio is presented in Table 7. In red loam soil T_4 (Urea+BM+WA) registered the highest leaf stem ratio of 1.04 and was on par withT_8 (0.99) , T_1 (0.89), T_{10} (0.88)and T_3 (0.69). T_2 (Urea+RP+WA) recorded lowest leaf stem ratio of 0.59 and was found to be on par with T_5 (OC+ RP + MOP) (0.62) and T_6 (OC + RP +WA) (0.66).

In lateritic soil T_{10} (control) registered the highest leaf stem ratio of 0.96 and was significantly superior to all other treatments. T_4 (Urea+BM+WA) recorded the lowest leaf stem ratio of 0.45 and was found to be on par with T_8 (OC+BM+WA) (0.50), T_5 (OC+ RP + MOP) (0.57), T_7 (OC+BM +MOP) (0.54), T_2 (Urea+RP+WA) (0.57) and T_1 (Urea+ RP+MOP) (0.52).

4.2.1.2.4 Shoot biomass plant $^{-1}$ (Table 8)

The data summarized in Table 8 reveal the significant influence of treatments on shoot biomass of amaranthus. In red loam soil the highest per plant shoot biomass (141.37 g plant $^{-1}$) was recorded in T_1 (Urea+ RP+MOP) and was on par with T_3 (Urea+ BM+MOP) (129.12 g plant $^{-1}$). The control treatment T_{10} recorded the lowest value of 9.72 g plant $^{-1}$ which was significantly inferior to all other treatments.

In lateritic soil also the highest mean value of 165.31g plant^{-1} was recorded by the treatment T_1 (Urea+ RP+MOP) and was significantly superior to all other treatments. The treatment T_{10} (control) recorded the lowest value 16.47 g plant $^{-1}$ which was significantly the lowest among all treatments.

Table 8. Effect of treatments on shoot biomass plant $^{-1}$ and root biomass plant $^{-1}$

Treatments	Shoot biomass plant $^{-1}$ (g)		Root biomass plant $^{-1}$ (g)	
	Red loam	Lateritic	Red loam	Lateritic
T_1	141.37	165.31	23.07	16.76
T_2	38.56	87.59	6.92	11.08
T_3	129.12	59.56	22.83	8.61
T_4	91.69	64.59	12.75	6.47
T_5	90.97	55.10	16.95	4.92
T_6	53.01	69.93	7.41	7.36
T_7	36.4	83.58	12.39	9.76
T_8	62.24	102.52	8.53	12.54
T_9	109.61	49.41	15.11	6.83
T_{10}	9.72	16.47	3.20	5.60
SE	8.08	7.48	2.43	1.18
CD (0.05)	24.001	22.252	7.210	3.511

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

4.2.1.2 .5 Root biomass plant $^{-1}$ (Table 8)

The data summarized in Table 8 reveal the significant influence of the treatments on root weight of amaranthus. In red loam soil T_1 (Urea+ RP+MOP) registered the highest root weight of 23.07 g plant^{-1} and was on par with T_3 (22.83 g) and T_5 (16.95 g). The lowest value of root weight 3.20 g was noticed in T_{10} (control).

In lateritic soil also the highest mean value of 16.76 g plant^{-1} was recorded by the treatment T_1 (Urea+ RP+MOP) which was significantly superior to all other treatments. It was followed by T_8 (12.54 g plant $^{-1}$), T_2 (11.08 g plant-^{1}) and T_7 (9.76 g plant $^{-1}$) which were statistically on par. T_5 (OC+ RP + MOP) recorded lowest value of 4.92 g plant $^{-1}$which was on par with control (T_{10}) .

4.2.1.2. 6 Total biomass yield plant $^{-1}$ (Table 9)

Table 9 presents total biomass yield plant^{-1}. It was observed that there was significant difference in total biomass yield due to treatments. The treatment combination (T_1) (Urea+ RP + MOP) recorded the maximum values for this character in both soils, 164.44 g plant $^{-1}$ in red loam soil and183.08 g plant $^{-1}$ in lateritic soil. In red loam soil T_1 was found to be on par with T_3 (Urea+ BM+MOP) (151.96 g plant $^{-1}$) and the treatment T_{10} (control) recorded the lowest value of 12.92 g plant $^{-1}$.

In lateritic soil T_1 was superior to all other treatments. The next best treatment T_8 (OC+BM+WA) (115.05 g plant $^{-1}$) was found to be on par with T_2 (98.68 g plant $^{-1}$) and T_7 (93.37 g plant $^{-1}$). The treatment T_{10} (control) recorded the lowest value of 22.08 g plant $^{-1}$.

4.2.1.2.7 Total yield(Table 9)

Table 9. presents total yield plot $^{-1}$. Statistical analysis of the data reveals that treatments significantly influenced total yield plot^{-1}. In red loam soil T_1 (Urea+ RP+MOP) registered the highest yield of 2.62 kg and was on par with T_6 (2.17 kg). The treatment T_{10} registered the lowest mean value of 0.32 kg.

Table 9. Effect of treatments on total biomass yield plant $^{-1}$and total yield plot^{-1}

Treatments	Biomass yield plant $^{-1}$ (g plant $^{-1}$)		Total yield plot $^{-1}$ (kg)	
	Red loam	Lateritic	Red loam	Lateritic
T_1	164.44	183.08	2.62	3.09
T_2	45.49	98.68	1.25	2.58
T_3	151.96	68.16	1.94	2.67
T_4	104.45	69.07	1.85	2.87
T_5	107.93	60.02	1.70	1.41
T_6	60.43	77.35	2.17	2.31
T_7	50.12	93.37	1.37	1.63
T_8	73.77	115.05	1.20	1.69
T_9	124.73	56.25	1.28	1.62
T_{10}	12.92	22.08	0.32	0.66
SE	9.76	8.59	0.17	0.42
CD (0.05)	28.985	25.541	0.5121	1.255

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

In lateritic soil also the highest mean value of 3.09 kg was recorded by the treatment T_1(Urea+ RP+MOP).T_1 was on par with,T_3 (2.67 kg),T_2 (2.58kg) and T_6 (2.31 kg).The treatment(control) T_{10} recorded the lowest value of 0.66 kg.

4.2.1.3 Quality parameters

4.2.1.3.1 Vitamin C (Table10)

The data summarized in Table 10 shows the significant influence of treatments on vitamin C content of amaranthus. The treatment combination(T_5) (OC+ RP + MOP) recorded the maximum values for this character in both soils, 71.59 mg 100 g^{-1}in red loam soil and 72.23 mg 100 g^{-1} in lateritic soil. T_5 was found to be on par with T_7 (OC+BM +MOP) (71.21 mg 100 g^{-1}) and T_8 (OC+BM+WA) (70.27 mg 100 g^{-1}) in red loam soil.The lowest value for vitamin C content 64.50 mg 100 $g^{-1}$was noticed in T_{10} (control).

In lateritic soil T_5 was superior to all other treatments. The treatment T_{10} (control) recorded the lowest value of 63.51 mg 100 g^{-1}

4.1.1.3.2 Beta carotene (Table 10)

Table 10 presents β carotene content in amaranthus. It was observed that there was significant difference in β carotene due to treatments. The treatment combination (T_5) (OC+ RP + MOP) recorded the maximum values for β carotene in crops in both soils, 6706.67 µg 100 g^{-1} in red loam soil and 6772.67 µg 100 g^{-1} in lateritic soil. In red loam soil T_5 was on par with T_3 (Urea+ BM+MOP) (6542.67 µg 100 g^{-1}). The treatment T_{10} (control) registered the lowest mean value of 2252.00 µg 100 g^{-1}.

In lateritic soil T_5 was superior to other treatments. The treatment T_{10} (control) recorded the lowest value of 2570.67 µg 100 g^{-1}

Table 10. Effect of treatments on vitamin C content, β carotene and crude protein content

Treatments	Vitamin C (mg 100 g $^{-1}$)		β carotene (µg 100 g $^{-1}$)		Crude protein (%)	
	Red loam	Lateritic	Red loam	Lateritic	Red loam	Lateritic
T_1	67.66	68.18	6116.00	5744.34	2.23	2.96
T_2	68.07	68.12	5501.00	5364.00	1.73	3.00
T_3	68.11	67.27	6542.67	6027.33	1.63	2.2
T_4	67.42	68.54	5060.00	5216.66	2.47	2.33
T_5	71.59	72.23	6706.67	6772.67	3.26	3.3
T_6	67.78	68.04	5277.33	4798.00	3.33	2.2
T_7	71.21	70.99	6127.33	5658.66	2.00	2.23
T_8	70.27	68.78	5283.66	5278.67	2.30	3.37
T_9	67.46	65.66	5124.00	5610.00	2.73	2.56
T_{10}	64.50	63.51	2252.00	2570.67	1.53	1.73
SE	0.75	0.36	126.58	104.36	0.99	0.80
CD (0.05)	2.223	1.074	375.191	310.110	0.293	0.242

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

4.2.1.3.3 Crude protein (Table 10)

The data presented in Table 10 shows the effect of different treatments on crude protein content in amaranthus. The treatments caused significant variation in crude protein. In red loam soil T_6 (OC + RP +WA) recorded the maximum crude protein content of 3.33 per cent and it was found to be on par with T_5 (OC+ RP + MOP) (3.26 per cent). The treatment T_{10} (control) recorded the lowest value of 1.53 per cent.

In lateritic soil the highest mean value of 3.37 percent was recorded by the treatment T_8 (OC+BM+WA) and was on par with T_5 (OC+ RP + MOP) (3.30 per cent).The treatment T_{10} (control) recorded the lowest value of 1.73 percent.

4.2.1.3.4 Nitrate content (Table 11)

The data summarized in Table 11 revealed the influence of treatments on nitrate content in amaranthus. The treatment T_{10} (control) recorded the minimum values for nitrate content in both soils, 0.13 per cent in red loam soil and 0.24 percent in lateritic soil.This antinutritional factor showed maximum value of 0.59 per cent for treatment T_8 (OC+BM+WA) in red loam soil and 0.52 per cent for treatment T_3 (Urea+ BM+MOP) in lateritic soil.

4.2.1.3.5 Oxalate content (Table 11)

Table 11 presents oxalate content in amaranthus. The treatment T_9 (KAU Org POP) recorded the lowest value of 0.85 per cent in red loam soil and the treatment T_8 (OC+BM+WA) registered the lowest value of 0.86 percent in lateritic soil. The treatment combination T_2 (Urea+RP+WA) recorded the highest value of 1.65 per cent in red loam soil and 1.35 per cent in lateritic soil.

Table 11 . Effect of treatments on nitrate content and oxalate content of amaranthus.

Treatments	Nitrate content(%)		Oxalate content(%)	
	Red loam	Lateritic	Red loam	Lateritic
T_1	0.42	0.43	1.28	1.13
T_2	0.31	0.34	1.65	1.35
T_3	0.42	0.52	1.05	1.07
T_4	0.51	0.33	1.16	1.24
T_5	0.44	0.42	1.39	0.87
T_6	0.29	0.32	1.08	1.01
T_7	0.34	0.25	1.22	1.14
T_8	0.59	0.51	1.44	0.86
T_9	0.4	0.46	0.85	0.89
T_{10}	0.13	0.24	1.39	1.30
SE	0.019	0.02	0.07	0.05
CD (0.05)	0.056	0.060	0.201	0.151

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

4.2.2 Effect of treatments on soil characters (soil biological indicators)

4.2.2.1 Soil megafauna

4.2.2.1.1 Earthworm (Table 12)

The data presented in Table 12 shows the effect of different treatments on earthworm count in soils. The counts were significantly influenced by the treatments in both soils. In red loam soil T_9 (KAU Org POP) recorded the maximum earthworm count of 6.67 nos. m^{-2} soil and it was found to be on par with T_8 (OC+BM+WA) (6.00 nos. m^{-2} soil). The lowest value of 1.00 nos.m^{-2} soil was shown by both T_{10} (Control) and T_1 (Urea+ RP+MOP).

In lateritic soil also T_9 (KAU Org POP) recorded the maximum earthworm count of 9.33 nos. m^{-2} soil and was significantly superior to all other treatments. The lowest values were shown by T_{10} (Control) and T_1 (Urea+ RP+MOP) each recording the same value of 1.00 no. earthworm m^{-2} soil.

4.2.2.1.2 Arthropods (Table 12)

The data summarized in Table 12 reveal the significant influence of treatments on soil arthropod count. In both soils T_6 (OC + RP +WA) recorded the highest value for this parameter. In red loam soil T_6 (OC + RP +WA) recorded a value of 68.00 nos.kg^{-1} soil and it was on par with T_8 (OC+BM+WA) (64.67 nos. kg^{-1}soil). The lowest value was shown by T_1 (Urea+ RP+MOP) (9.67 nos.kg^{-1} soil). In lateritic soil T_6 (OC + RP +WA) recorded maximum arthropod count of 94.00 nos. kg^{-1} soil and was significantly superior to all other treatments. The lowest mean value of 12.00 nos. kg^{-1} soil was registered by the treatment T_1 (Urea+ RP+MOP).

Table 12 . Effect of treatments on earthworm count and arthropod count

Treatments	Earthworm count (nos.m^{-2} soil)		Arthropods count (kg^{-1} soil)	
	Red loam	Lateritic	Red loam	Lateritic
T_1	1.00	1.00	9.67	12.00
T_2	1.33	1.67	16.00	16.00
T_3	2.00	1.33	21.33	26.00
T_4	2.67	1.67	14.33	12.67
T_5	1.67	2.00	35.00	39.33
T_6	2.67	2.33	68.00	94.00
T_7	4.00	2.00	44.33	24.00
T_8	6.00	7.67	64.67	78.67
T_9	6.67	9.33	60.67	77.00
T_{10}	1.00	1.00	16.00	18.33
SE	0.29	0.28	1.62	1.98
CD (0.05)	0.881	0.822	4.801	5.871

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

4.2.2.2 Soil microflora (Table13)

Table 13 shows the changes in microbial population due to various treatments under field conditions. Bacterial, fungal and actinomycetes population were significantly influenced by the treatments and in both soils T_6 recorded the maximum values for all these three parameters which were superior to all others.

4.2.2.2.1 Bacteria (Table 13)

For bacteria in red loam soil the highest mean value was recorded by treatment T_6 (OC + RP +WA) 196.00× 10^4 cfu g^{-1} soil and the lowest mean value (65.33× 10^4 cfu g^{-1} soil) was recorded by the treatment T_{10} (Control)

In lateritic soil also the highest mean value of 215.33× 10^4 cfu g^{-1} soil was recorded by the treatment T_6 (OC + RP +WA). The lowest mean value of 76.67 × 10^4 cfu g^{-1} soil was registered by the treatment T_1 (Urea+ RP+MOP), which was significantly the lowest.

4.2.2.2.2 Actinomycetes (Table 13)

For actinomycetes population the highest mean value of 9.33× 10^3cfu g^{-1} soil was recorded by the treatment T_6 (OC + RP +WA. The lowest mean value of 1.33× 10^3 cfu g^{-1} soil was recorded by the treatment T_3 (Urea+ BM+MOP) and it was on par with T_2 (Urea+RP+WA) (2.33 × 10^3 cfu g^{-1} soil), T_1 (Urea+ RP+MOP) (1.67 × 10^3 cfu g^{-1} soil), T_4 (Urea+BM+WA) (1.67 × 10^3 cfu g^{-1} soil), and T_{10} (1.67 × 10^3 cfu g^{-1} soil).

In lateritic soil the highest mean value of 8.67× 10^3 cfu g^{-1} soil was again recorded by the treatment T_6 (OC + RP +WA) and was superior to all other treatments. T_1 (Urea+RP+MOP) registered the lowest value of 1.33× 10^3 cfu g^{-1} soil.

Table 13 . Effect of treatments on bacterial, actinomycetes and fungal population

Treatments	Bacteria ($\times 10^4$ cfu g^{-1}soil)		Actinomycetes ($\times 10^3$ cfu g^{-1}soil)		Fungi ($\times 10^4$ cfu g^{-1}soil)	
	Red loam	Lateritic	Red loam	Lateritic	Red loam	Lateritic
T_1	69.33	76.67	1.67	1.33	3.00	4.00
T_2	80.00	94.00	2.33	2.67	6.67	4.33
T_3	90.00	83.67	1.33	2.00	2.67	4.67
T_4	84.00	89.33	1.67	2.00	4.67	6.67
T_5	97.33	120.00	4.00	4.67	8.33	8.67
T_6	196.00	215.33	9.33	8.67	12.66	14.67
T_7	142.00	114.67	5.67	6.33	6.67	11.00
T_8	152.33	136.33	7.67	5.67	9.00	12.33
T_9	116.67	127.33	5.00	6.00	5.33	8.67
T_{10}	65.33	90.00	1.67	2.00	2.33	5.33
SE	2.43	2.11	0.52	0.51	0.58	0.84
CD (0.05)	7.213	6.671	1.562	1.521	1.720	2.493

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

4.2.2.2.3 Fungi (Table13)

Regarding the fungal count in red loam soil the treatment T_6 (OC + RP +WA) registered the highest mean value of 12.66×10^4 cfu g^{-1} soil and was superior to all other treatments. Control plot T_{10} registered the lowest value of 2.33×10^4 cfu g^{-1} soil to which T_1 (Urea+ RP+ MOP) and T_3 (Urea+ BM+MOP) were on par recording values of 3.00 and 2.67×10^4 cfu g^{-1} soil respectively.

In lateritic soil also T_6 recorded the highest mean value of 14.67×10^4 cfu g^{-1} soil. It wasfollowed by the treatments T_8 (OC+BM+WA) (12.13×10^4 cfu g^{-1} soil) and T_7 (11.00×10^4 cfu g^{-1} soil) and they were on par. The lowest mean value of 4.00×10^4 cfu g^{-1} soil was recorded by the treatment T_1 (Urea+RP+MOP) which was on par with T_2 (Urea+RP+WA) recording 4.33×10^4 cfu g^{-1} soil, T_3 (Urea+ BM+MOP) recording $4,67\times10^4$ cfu g^{-1} soil and T_{10} (control) recording 5.33×10^4 cfu g^{-1} soil.

4.2.2.3 Soil Enzymes

4.2.2.3.1 Urease (Table 14)

The data summarized in Table 14 reveals the significant influence of treatment on soil urease activity. In red loam soil the highest value 151.84 µg NH_4^+-N g^{-1}soil d^{-1} was recorded for the treatment T_4 (Urea+BM+WA)and was found to be significantly superior to other treatments. The lowest value 81.73 µg NH_4^+-N g^{-1}soil d^{-1} was recorded by T_9 . (KAU Org POP).

In lateritic soil also the highest value was recorded for the treatment T_4 (Urea+BM+WA) (177.74 µg NH_4^+-N g^{-1}soil d^{-1}) and it was found to be superior to all other treatments. The lowest value for T_7 (OC+BM +MOP) recorded 84.62 µg NH_4^+-N g^{-1}soil d^{-1} which was significantly the lowest.

4.2.2.3.2 Phosphatase (Table 14)

Table 14 shows the phosphatase activity of soil at the harvest time of the crop. The mean values for the phosphatase ranged from 61.31 to 89.67 µg P-

Table 14. Effect of treatments on soil phosphatase and urease activity

Treatments	Urease ($\mu g\ NH_4^+$-N g^{-1}soil d^{-1})		Phosphatase (μg P-nitrophneol g^{-1} soil h^{-1})	
	Red loam	Red loam	Lateritic	Lateritic
T_1	113.17	75.30	61.69	106.68
T_2	124.51	89.67	75.05	164.18
T_3	138.89	65.27	71.21	143.37
T_4	151.84	79.11	81.44	177.74
T_5	91.07	78.30	73.85	95.57
T_6	104.13	80.19	72.42	104.32
T_7	93.05	83.69	80.23	84.62
T_8	85.08	78.12	82.84	94.13
T_9	81.73	81.79	65.66	96.07
T_{10}	82.40	61.31	59.34	96.02
SE	1.51	1.17	0.85	1.64
CD (0.05)	4.480	3.481	2.531	4.862

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

nitrophenol g^{-1} soil h^{-1}. In red loam soil the highest value of phosphatase activity (89.67 µg P-nitrophenol g^{-1} soil h^{-1}) was noticed for the treatment T_2 (Urea+RP+WA) and was found to be significantly superior to other treatments. The lowest value of 61.31 µg P-nitrophenol g^{-1} soil $h^{-1}$was recorded by control which was inferior to all others.

In lateritic soil the highest value of phosphatase activity was noticed for the treatment T_8 (OC+BM+WA) (82.834 µg P-nitrophneol g^{-1} soil h^{-1}) and was found to be on par withT_4 (81.44 µg P-nitrophenol g^{-1} soil h^{-1}). The lowest value of phosphatase activity was noticed in T_{10} and it was 59.34 µg P-nitrophenol g^{-1} soil h^{-1}. This was on par with T_1(Urea+RP+MOP) recording a value of 61.69 µg P-nitrophenol g^{-1} soil h^{-1}.

4.2.2.3.3 Dehydrogenase (Table 15)

Table 15 shows the dehyrogenase activity of soil at the end of the crop growth. In red loam the mean values for dehydrogenase ranged from 113.48 to 273.8957µg TPF g^{-1} 24 h^{-1}. The highest value was noticed for the treatment T_8 (OC+BM+WA) (273.89 µg TPF g^{-1} 24 h^{-1}) and was on par with T_6 (260.59 µg TPF g^{-1} 24 h^{-1}). The lowest value was recorded in the control plot T_{10} (113.48 µg TPF g^{-1} 24 h^{-1}). Treatments T_1 (121.91 µg TPF g^{-1} 24 h^{-1}) and T_3 (125.59 µg TPF g^{-1} 24 h^{-1}) were on par with this.

In lateritic soil the mean values for dehydrogenase ranged from 87.19 to 211.99 µg of TPF hydrolysed g^{-1} of soil 24 hrs. The highest value was noticed for the treatment T_8 (OC+BM+WA) (211.99 µg TPF g^{-1} 24 h^{-1}) which was found to be on par with T_9 (200.28 µg TPF g^{-1} 24 h^{-1}) and T_6 (189.57µg TPF g^{-1} 24 h^{-1}). The lowest value was recorded in the control plot T_{10} (87.19 µg TPF g^{-1} 24 h^{-1}).TreatmentsT$_3$ (Urea+ BM+MOP) (119.53 µg TPF g^{-1} 24 h^{-1}), T_4 (129.16 µg TPF g^{-1} 24 h^{-1}) and T_5 (118.35 µg TPF g^{-1} 24 h^{-1}) were on par with this.

Table 15. Effect of treatments on dehydrogenase activity and soilrespiration

Treatments	Dehyrogenase activity (μg TPF g^{-1} 24 h^{-1})		Soil respiration (mg CO_2 100 g^{-1} d^{-1})	
	Red loam	Red loam	Lateritic	Lateritic
T_1	121.91	2.40	3.36	140.27
T_2	140.37	2.87	4.11	89.08
T_3	125.59	3.01	4.87	119.53
T_4	159.71	5.06	4.25	129.16
T_5	168.05	4.98	6.51	118.35
T_6	260.59	6.10	7.26	189.57
T_7	153.46	5.28	6.97	129.26
T_8	273.89	5.95	5.72	211.99
T_9	243.93	6.49	7.77	200.28
T_{10}	113.48	2.14	3.15	87.19
SE	4.78	022	0.23	14.54
CD (0.05)	14.191	0.651	0.700	43.192

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

4.2.2.4 Soil respiration (Table 15)

From the results (Table 15) it can be inferred that application of various treatment significantly influenced soil respiratory activity. The treatment T_9 (KAU Org POP) registered the maximum value of 6.49 mg CO_2 100 g^{-1} $d^{-1}$and was found to be on par with T_8 (5.95 mg CO_2 100 g^{-1} d^{-1}) and T_6 (6.10 mg CO_2 100 g^{-1} d^{-1}). The lowest value of 2.14 mg CO_2 100 g^{-1} $d^{-1}$was recorded by the treatment T_{10} (control) .

In lateritic soil also treatment T_9 (KAU Org POP) registered the maximum value of 7.77 mg CO_2 100 g^{-1} d^{-1} and was found to be on par with T_6 (OC + RP +WA) (7.26mg CO_2 100 g^{-1} d^{-1}). The lowest value of 3.15 mg CO_2 100 $g^{-1}d^{-1}$was recorded by the treatment T_{10} (control) to which T_1 (Urea+ RP+MOP) was on par recording a value of 3.36 mg CO_2 100 g^{-1} d^{-1}.

4.2.2.5 Organic carbon (Table 16)

Analysis of data revealed that soil organic carbon was significantly influenced by different treatments in both soils. In red loam soil the highest mean value of 1.28 per cent was registered by the treatment T_5 (OC+ RP + MOP) which was on par with T_9 (1.23). The treatment T_3 (Urea+ BM+MOP) registered the lowest mean value of 0.35 per cent which was significantly the lowest.

In lateritic soil the treatment T_9 (KAU Org POP) registered the highest mean value of 1.53 per cent and it was found to be on par with T_6 (OC + RP +WA) (1.46 percent) and T_8 .The lowest mean value for soil organic carbon was recorded by the treatment T_{10} (control), registering a mean value of 0.46 per cent which was significantly the lowest.

4.2.2.6. Available N (Table 16)

The data presented in Table 16 shows the effect of different treatments on available N in soils. The treatments caused significant variation in available N content. In red loam soil T_6 (OC + RP +WA) recorded the maximum N content of 281.67 kg $ha^{-1}$and it was found to be on par with T_3 (262.50 kg ha^{-1}), T_8 (258.34

Table16. Effect of treatments on soil organic C and available N content

Treatments	Soil organic carbon(%)		Available N (kg ha $^{-1}$)	
	Red loam	Lateritic	Red loam	Lateritic
T_1	0.55	0.84	250.00	325.00
T_2	0.64	0.66	216.67	258.33
T_3	0.35	0.85	262.50	320.83
T_4	0.84	1.19	245.00	225.00
T_5	1.28	1.33	234.80	280.17
T_6	1.08	1.46	281.67	250.00
T_7	1.03	1.43	232.10	283.30
T_8	0.95	1.41	258.34	250.00
T_9	1.23	1.53	216.67	287.50
T_{10}	0.39	0.46	191.67	166.67
SE	0.04	0.04	12.53	11.19
CD (0.05)	0.151	0.121	37.221	33.263

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

kg ha $^{-1}$), T_1 (250.00 kg ha $^{-1}$) and T_4 (245.00 kg ha $^{-1}$). The treatment T_{10} (control) recorded lowest N content of 191.67 kg ha $^{-1}$

In lateritic soil the treatment T_1 (Urea+ RP+MOP) registered the highest mean value of 325.00 kg ha $^{-1}$ and it was found to be on par with T_3 (Urea+ BM+MOP) (320.83 kg ha $^{-1}$) and the lowest mean value for N content was recorded by the treatment T_{10}, which registered a mean value of 166.67 kg ha $^{-1}$.

4.2.2.6 Available P (Table 17)

Analysis of data revealed that available P content was significantly influenced by different treatments in both soils. The treatment combination (OC+BM +MOP) (T_7) recorded the maximum values for available P content in both soils, 114.98 kg ha $^{-1}$ in red loam soil and 128.59 kg ha $^{-1}$ in lateritic soil. T_7 was found to be on par with T_3 (Urea+ BM+MOP) (107.97 kg ha $^{-1}$). In red loam soil the lowest value 13.84 kg ha $^{-1}$ was noticed in T_{10} (control).

In lateritic soil the treatment T_7 was found to be on par with T_5 (123.89) kg ha $^{-1}$ and T_9 (123.66 kg ha^{-1})The lowest value17.18 kg ha^{-1}was noticed in T_{10} (control).

4.2.2.7 Available K (Table 17)

Table 17 presents available K content in soil. The data revealed that the treatments caused significant variation in K content in both soils. In red loam soil the highest mean value of 296.98 kg ha $^{-1}$was registered by the treatment T_6 (OC + RP +WA) which was on par with T_4 (278.24 kg ha $^{-1}$) and T_9 (264.95 kg ha $^{-1}$). The treatment T_{10} (control) registered the lowest mean value of 47.34 kg ha $^{-1}$.

In lateritic soil the treatment T_7 (OC+BM +MOP) registered the highest mean value of 128.59 kg ha $^{-1}$ and it was found to be on par with T_5 (123.89 kg

Table17. Effect of treatments on soil available P and available K content

Treatments	Available P ($kg\ ha^{-1}$)		Available K ($kg\ ha^{-1}$)	
	Red loam	Lateritic	Red loam	Lateritic
T_1	70.64	72.84	151.83	72.48
T_2	72.74	114.86	76.38	114.87
T_3	107.97	74.09	119.28	74.09
T_4	54.50	104.82	278.24	104.82
T_5	70.18	123.89	126.86	123.89
T_6	42.38	60.25	296.98	60.25
T_7	114.98	128.59	109.39	128.59
T_8	47.32	72.08	213.36	72.08
T_9	79.08	123.66	264.95	123.66
T_{10}	13.84	17.18	47.34	17.17
SE	3.11	2.68	17.70	2.68
CD (0.05)	9.252	7.973	52.601	7.971

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

ha^{-1}) and T_9 (123.66 kg ha^{-1}). The lowest mean value (17.17 kg ha^{-1}) was recorded by the treatment T_{10} and it was significantly inferior to all others.

4. 3 Economics of Cultivation

Table 18 shows economics of cultivation of amaranthus crop. In red loam soil the treatment T_1 (Urea+ RP+MOP) recorded the highest B:C ratio (1.73) which is on par with the treatment T_6 (1.67). The lowest B:C ratio was recorded by the treatment T_9 (KAU Org POP) with a mean value of 0.60.

In lateritic soil also T_1 (Urea+ RP+MOP) recorded the highest B:C ratio of 1.85, which was followed by T_3 (Urea+ BM+MOP) (1.67). The treatment T_9 (KAU Org POP) recorded the lowest B:C ratio of 1.08.

Table 18. Effect of treatments on Benefit Cost ratio

Treatments	Benefit –Cost ratio	
	Red loam	Lateritic
T_1	1.73	1.85
T_2	1.15	1.63
T_3	1.63	1.67
T_4	1.52	1.60
T_5	1.18	1.29
T_6	1.67	1.56
T_7	1.13	1.14
T_8	1.09	1.10
T_9	0.60	1.08
T_{10}	1.11	1.14
SE	0.02	0.03
CD (0.05)	0.061	0.092

T_1 Urea+Rock phosphate+Muriate of potash(KAU POP, 2007)

T_2 Urea+Rock phosphate+Wood ash

T_3 Urea+Bone meal+Muriate of potash

T_4 Urea+Bonemeal+Wood ash

T_5 Oil cake+Rock phosphate+Muriate of potash

T_6 Oil cake+Rock phosphate+Wood ash

T_7 Oil cake+Bone meal+Muriate of potash

T_8 Oil cake+Bone meal+ Wood ash

T_9 KAU Organic POP(2009)

T_{10} Control (No manure, No fertilizer)

Table. 19. Improvement of soil health as measured quantitatively using biological properties of soils as evaluatory tools

Sl. no	Biological property	Red loam soil		Lateritic soil	
		Best treatment	Increase Over the initial value	Best treatment	Increase Over the initial value
1	Earthworm population	T_9 (KAU Org POP)	From 0 to 6.67 no. m^{-2}	T_9(KAU Org POP)	From 0 to 9.33 no. m^{-2}
2	Arthropod population	T_6(OC + RP +WA)	4.25 fold	T_6(OC + RP +WA)	2.94 fold
3	Bacterial population	T_6(OC + RP +WA)	12.25 fold	T_6(OC + RP +WA)	9.36 fold
4	Actinomycetes population	T_6(OC + RP +WA)	From 0 to 9.33×10^{3} cfu g^{-1}	T_6(OC + RP +WA)	6.52 fold
5	Fungal population	T_6(OC + RP +WA)	3.88 fold	T_6(OC + RP +WA)	2.27 fold
6	Urease activity	T4(Urea+BM+WA)	2.43 fold	T4(Urea+BM+WA)	2.70 fold
7	Phosphatase activity	T2(Urea+RP+WA)	1.48 fold	T8(OC+BM+WA)	1.57 fold
8	Dehydrogenase activity	T8(OC+BM+WA)	3.57 fold	T8(OC+BM+WA)	2.57 fold
9	Soil respiration	T9(KAU Org POP)	2,26 fold	T9(KAU Org POP)	1.96 fold
10	C mineralization potential	T5(OC+ RP + MOP)	3.12 fold	T9(KAU Org POP)	3.40 fold
11	N mineralization potential	T6(OC + RP +WA)	1.15 fold	T1(Urea+RP+MOP)	1.72 fold

Discussion

5. DISCUSSION

The salient results of investigation carried out at college of Agriculture, Vellayani to study the changes the major biological properties of soils undergo when the nutrient requirements of crops grown on these are met by organic and inorganic sources are briefly discussed in this chapter. The investigations included laboratory studies and two field experiments in which amaranth crop was raised on two soil types of Vellayani, red loam and lateritic. The treatments were different combinations of the major plant nutrients, N, P and K through their organic sources (oil cake, bone meal and wood ash respectively) and inorganic sources (urea, rock phosphate and muriate of potash respectively).

5.1 PLANT CHARACTERS

5.1.1 Growth characters

The results presented in the preceding chapter (Table 4,5 & 6) show that the biometric observations *viz.*, plant height, number of leaves, number of branches, stem girth, root length and root volume were all significantly influenced by different treatments.

The treatment combination T_3 (Urea+ RP+MOP) which supplied both N and K in inorganic forms and P in organic form recorded the maximum values for plant height in both soils. This may be due to the combined effect of organics and inorganics and immediate availability of nutrients from soluble inorganic fertilizers. This is in conformity with the findings of Islam *et al.* (2011) who reported that manures in combination with chemical fertilizers had significant impact on plant height in red amaranthus. Amaranthus being a C_4 plant CO_2 fixation is high N demand is also considerable during the vegetative growth and formation of new leaves, stem and root (Delvin and Witham, 1986). Mengal and Kirkby (1987) reported that meristamatic tissues have a very active protein metabolism and photosyntnates transported to these sites are used primarily for

synthesis of nucleic acid and proteins. For this reason, during vegetative stage, N nutrition controls the growth rate of crops. As this treatment supplied N in the inorganic form, immediate availability of N from soluble inorganic fertilizer may be the possible reason for increased vegetative growth. In addition to this bone meal which was the organic source of P in this treatment contains substantial amount of N which might have been released N at a steady slow rate prolonging N availability to the crop due to its residual effect.

The combination of all major plant nutrients in inorganic sources T_1 (Urea+ RP+ MOP) recorded the maximum values for stem girth in red loam soil and number of branches plant $^{-1}$ in lateritic soil. This result is in agreement with the view of Islam *et al.* (2011) who reported that the maximum stem circumference and number of branches in Indian spinach was found in the inorganically fertilized plots. In lateritic soil the treatment combination T_2 which supplied both N and P in inorganic form recorded the maximum values for stem girth . Uddin *et al.* (2004) and Iqbal (2008) also reported that integrated nutrient management increased stem girth in red amaranthus.

Regarding number of branches plant $^{-1}$ the treatment combination (T_3) which supplied both N and K in inorganic form and P in organic form recorded the maximum value in red loam soil which was on par with T_9 (KAU Org POP). The same treatment had registered the maximum value for plant height in this soil and the increased plant height might have induced the branching nature of the plant. Similar results were also reported by Noor *et al.* (2008) in case of red amaranth.

The combination of all major plant nutrients in organic forms T_8 (OC+ BM+WA) recorded the maximum value for number of branches plant $^{-1}$in lateritic soil and maximum number of leaves plant $^{-1}$ in red loam soil. Sharu (2000) reported that in chilli growth characters like plant height, number of branches and dry matter accumulation increased as a result of neem cake application. Growth characters like number of branches plant $^{-1}$ and plant spread

showed significant variation in coleus due to application of rock dust @ 10 t ha $^{-1}$ mixed with equal quantity of FYM(Divya, 2008).

5.1.2 Yield and yield attributes.

Significant differences were observed among yield attributing characters like leaf weight plant $^{-1}$, stem weight plant $^{-1}$, shoot biomass plant $^{-1}$, root biomass plant $^{-1}$, biomass yield plant $^{-1}$ and total yield plot $^{-1}$ (Table 7,8 &9).

The combination of all major plant nutrients in inorganic sources T_1 recorded the maximum values for yield in both soils, 2.62 kg plot $^{-1}$ in red loam soil and 3.09 kg plot^{-1} lateritic soil, which work out to 11651.87 kg ha^{-1} and 13740.76 kg ha^{-1} respectively in these soils. Most of the yield attributing factors also registered significantly the highest values for this treatments. This treatment is the accepted fertilizer recommendation of Kerala Agricultural University for amaranthus as per KAU (POP). As this is a tested and proved practice the superiority of this treatment over all other practices is unquestionable, especially in the case of crop yield. This might be due to the increased availability all the major nutrients from inorganic fertilizers. The plants received more readily available applied nutrients, which might have encouraged more vegetative growth. Agreeing reports to this have been put forward by Islam *et al,* (2011) for Indian spinach in clayey soil, Sultana (2006) for radish in sandy loam soil, Sarkar (2005) for red amaranthus in loamy soil.

5.1.3 Quality parameters

The treatments resulted in causing significant variations in the quality characters of the crop as evidenced by data presented in Table 10 & 11. From studies on recycling of organic materials Huang and Lin (2001)found that the application of organic manures combined with chemical fertilizers improved the quality of crops.

5.1.3.1 Betacarotene

The treatment combination T_5 (OC+ RP + MOP) which is a combination of N alone in the organic form with both P and K in inorganic forms recorded the maximum values for β carotene in amarantus grown on both soils. This may be due to combined effect of neem cake and rock phosphate as reported by Nath (1967) and Subbiah (1979) who advocated the application of N in the form of manure as basal dressing and P and K as fertilizers for top dressing after every cutting of amaranthus. Nitrogen content of the plant is particularly related to β-carotene content. Scharrer and Burke (1953) reported that increasing level of N supply raised carotene content in plants. Sheeba (2004) showed that the treatments with organic sources of plant nutrients recorded the highest values for beta carotene content, protein content and the lowest fiber and oxalates content in amaranthus.

5.1.3.2 Crude protein

In red loam soil T_6 (OC + RP +WA) recorded the maximum crude protein content of 3.33 percent and it was found to be on par with T_5 (3.26 per cent) . In lateritic soil the highest mean value of 3.37 percent was recorded by the treatment T_8 (OC+BM+WA) and was on par with T_5 (3.30 per cent). In both soils the N source applied in organic form recorded the maximum crude protein content. Protein content in amaranthus increased with the application of organic source of N fertilizers. Increasing the level of organic manure increases the N availability to plants. Nitrogen thus derived is metabolized *via* ammonium into glutamic acid. Carbon skeleton provided by photosynthesis are incorporated in the process of amino acid synthesis which are stored as proteins (Tisdale *et al.*, 1995).

5.1.3.3 Vitamin C

Vitamin C content in the plant followed a trend similar to that of beta carotene. The treatment combination T_5 (OC+ RP+MOP) which is a combination of N alone in the organic form with both P and K in the inorganic forms recorded

the maximum values of 71.59 and 72.23 mg 100 g^{-1} in both soils. Manjumdar *et al.*(2000) found that combined application of organic and inorganic fertilizers resulted in high ascorbic acid content in plant which be attributed to the high carbohydrate metabolisam. Similar results were also observed by Shibilamary and Balakrishnan (1990) observed significant increase in vitamin C content of several vegetables with increased levels of K application. Since this treatment included K in the inorganic form, its easy availability might have increased the vitamin C content.

5.1.3.4 Nitrates and oxalates

Amaranthus is known to accumulate high levels of anti nutritional factors like oxalates and nitrates which on ingestion by human beings lead to formation of kidney stones and decreased bioavailabity of nutrients (Radek & Savage, 2008). The control plot (T_{10}) recorded the minimum value of 0.13 and 0.24 per cent nitrate content in red loam and lateritic soil respectively. Oxalate content showed the least value of 0.85 per cent for treatment T_9 (KAU organic POP) in red loam and 0.86 per cent for treatment T_8 (all major nutrients in organic form) in lateritic soil. Organic farming has widely been accepted as the key to food safety as exclusion of fertilizers from the farming practice will produce safe food for mankind without poisonous toxins, especially leafy vegetables. The present findings also support this view as the plants in the control plots utilized only the natural resource of nutrients in the soil and in the organic plots, only from the organic sources. Accumulation of nitrates results from an imbalance between the uptake and translocation of nitrates by the xylem (Maynard *et al.*, 1976). As readily available sources of nutrients especially N were not supplied to plants receiving the above treatments this imbalance might not have occurred leading to non accumulation of nitrates.

5.2 SOIL CHARACTERS (SOIL BIOLOGICAL INDICATORS)

5.2.1 Soil macrofauna

5.2.1.1Earthworm

The data presented in Table 12 and depicted in Fig.4. shows the effect of different treatments on earthworm count in soils. The counts were significantly influenced by the treatments in both soils. In both soils KAU organic POP recorded the maximum value. This treatment included application of two organic sources of nutrients viz vermicompost and poultry manure to the crop. Vermicompost contains cocoons of earthworm which naturally increase their population. Similar results were reported by Kotcon (2011) who opined that compost amendments increased the population of earthworm. Another reason might be the increased organic matter content due to vermicompost application. The addition of animal manure, sewage wastes, and spent malt from breweries, paper pulp, or potato processing waste all showed a positive effect on earthworm numbers (Edwards *et al.,* 1995). According to him additions of organic material can double or triple earthworm numbers in a single year. Form her study Fasila (2012) reported that multiplication of native as well as exotic earthworms was higher in vermicompost applied soil.

5.2.1.2 Arthropods

The data presented in Table 12 shows the effect of different treatments on arthropod count in soils. 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 breakdown and comprehensively ecological restoration. Application of inorganic and organic fertilizers can indirectly but positively affect soil microbes and animals by increasing plant growth and stimulating root exudation, both of which lead to a greater input of organic substrates. Community structure and body size of soil organisms are also affected by fertilization (Mueller *et al.*, 1993, Verschoor *et al.*,

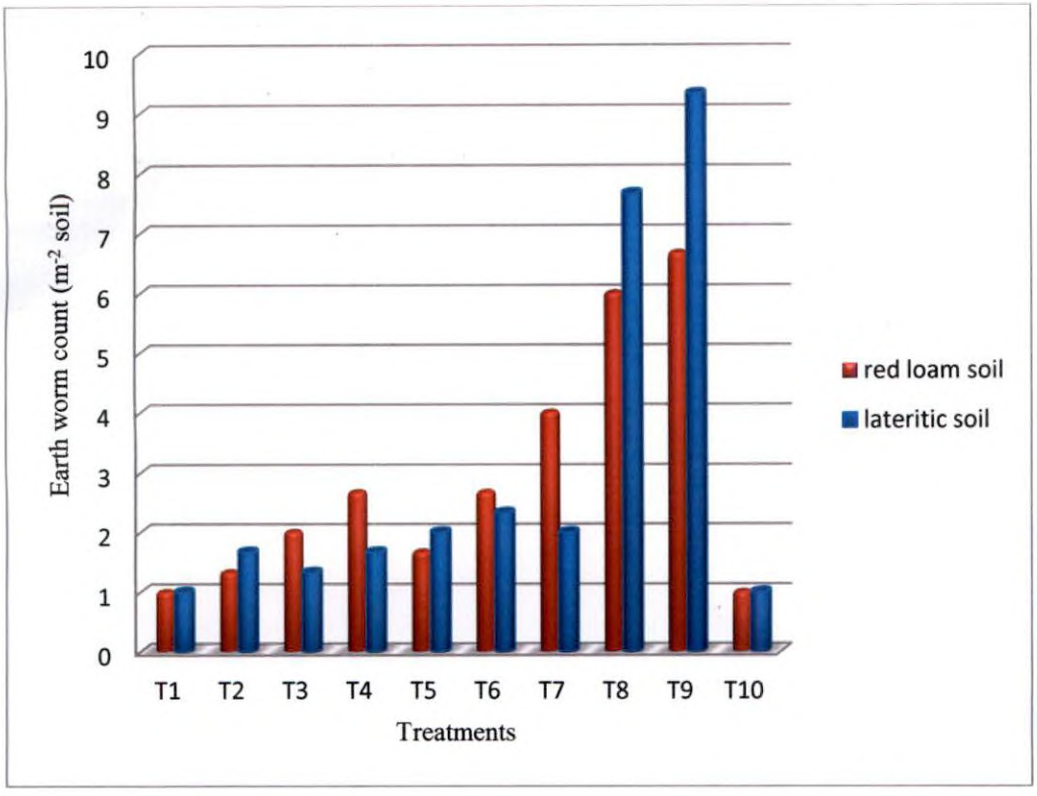


Fig. 4. Effect of treatments on earthworm count (m^{-2} soil)

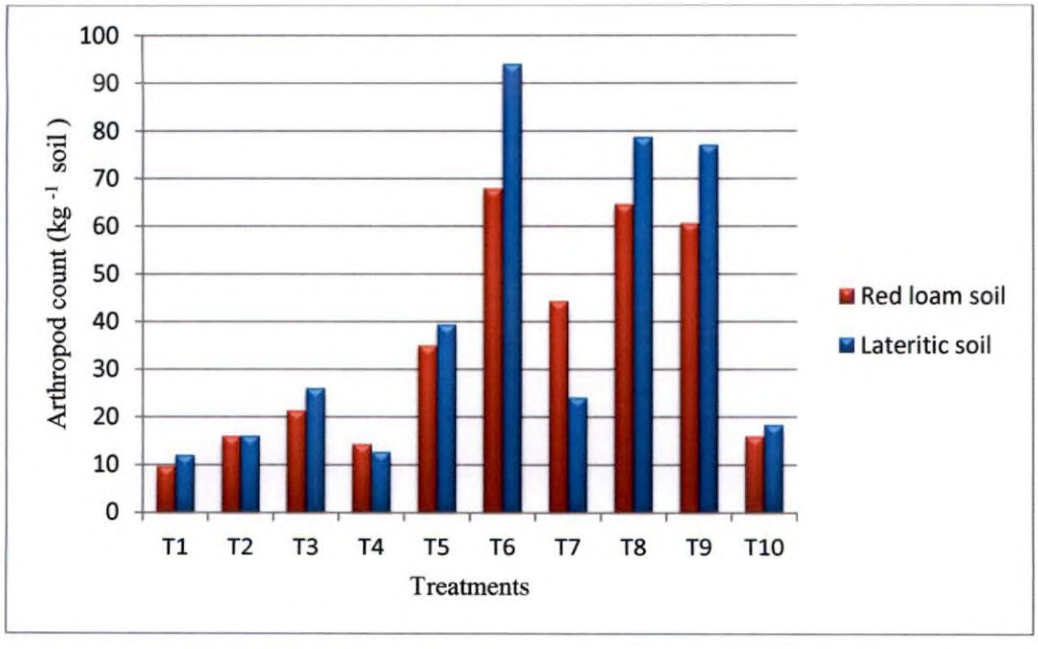


Fig. 5. Effect of treatments on arthropod count (kg^{-1} soil)

2001).The treatment combination (OC + RP +WA) in which both N and K were applied through organic sources recorded highest population of arthropods in both soils. Similar results were reported by Miyazawa *et al.* (2002) who opined that organic manure application increased the numbers of micro arthropods. This might be due to the increased supply of various nutrients, enhanced plant growth and altered soil conditions brought about by organic manures. Organic matter is crucial for the stability of the soil structure and it serves as an energy source for microorganisms which meso fauna consume. The lowest population is recorded in Urea+RP+MOP treatment combination in which all nutrients were applied inorganically. 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 soil pH, through increase in nitrate ions. The acidity of soil can exerts a depressing influence on many Collembolan species of micro arthropods. Nitrogen fertilizer can also create a high osmotic pressure in the soil solution which has a negative effect on the abundance of soil fauna (Andren, 1984).

5.2.2 Soil microflora

According to Kennady and Papendick (1995) soil microbial populations and activities function as excellent indicators of soil health. The treatment combination (T_6) (OC+RP+WA) which provides both N and K organically to the crop recorded the maximum values for all the microbial populations estimated viz bacteria, fungi and actinomycetes in both soils. The possible reason for this could be the enhanced organic carbon content of the soil as a result of organic manure application as compared to inorganic fertilizers. Besides this, the organic manure addition would have resulted in increased secondary and micronutrients in the soil which might have helped to increase the microbial population. Krishnakumar *et al.* (2005) reported that combined application of FYM and neem cake increased the populations of bacteria, fungi and actinomyctes.

Soil fungal population is favoured largely by organic farming systems. Greater propagule densities of actinomycetes in soils of tomato field under

organic cultivation compared with conventional production systems in California have also been reported (Drinkwater *et al.,* 1995). The addition of organic maures favoured a significantly greater input of organic carbon, which increased bacterial populations (Fraser, 1998).

5.2.3 Soil enzymes

Soil enzymes are the integral part of soil biochemical processes and therefore can be used as functional indicators of microbial communities. Responsiveness of enzyme to environmental disturbances make them potential indicators of soil biological quality (Buckly and Schmidt, 2001). Soil enzymes are produced by living organisms and are mainly microbial in origin. Incorporation of organic amendments in soil promotes microbial growth and activity by provding nutrients and carbon and there by improve enzyme activity (Balasubramaniam *et al.*, 1972). Soil enzymes such as dehydrogenase, phosphatase and urease were significantly influenced by different treatments as shown in the tables14,15 and Fig. 6,7 & 8.

5.2.3.1 Urease

Urease catalyzes the hydrolysis of urea to CO_2 and NH_3 and its activity in soil decides directly the hydrolysis of urea and indirectly its loss due to volatilization and denitrification (Srinivas *et al.*, 2004).

The treatment combination T_4 (Urea+BM+WA) which is a combination of N alone in inorganic form and both P and K in organic forms recorded the maximum values for soil urease activity in both soils. Higher urease activity might be due addition of amide form of nitrogen applied through urea. The increased rate of nitrogen application and various biomaterial added to soil as well as root exudates promoted the production of nitrogenous substances which induced the urease activity. These findings corroborate with findings of Raj and Yadav (2011) who have reported that the combined application of organic and inorganic sources showed higher values for soil urease activity 60 days after incubation.

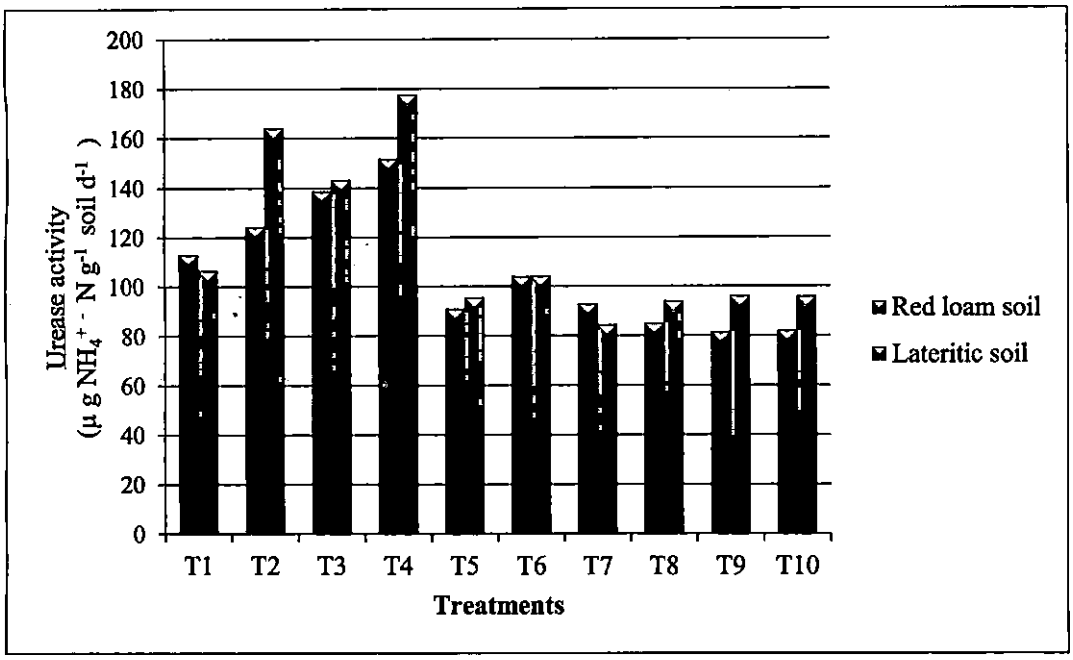


Fig. 6. Effect of treatments on soil urease activity

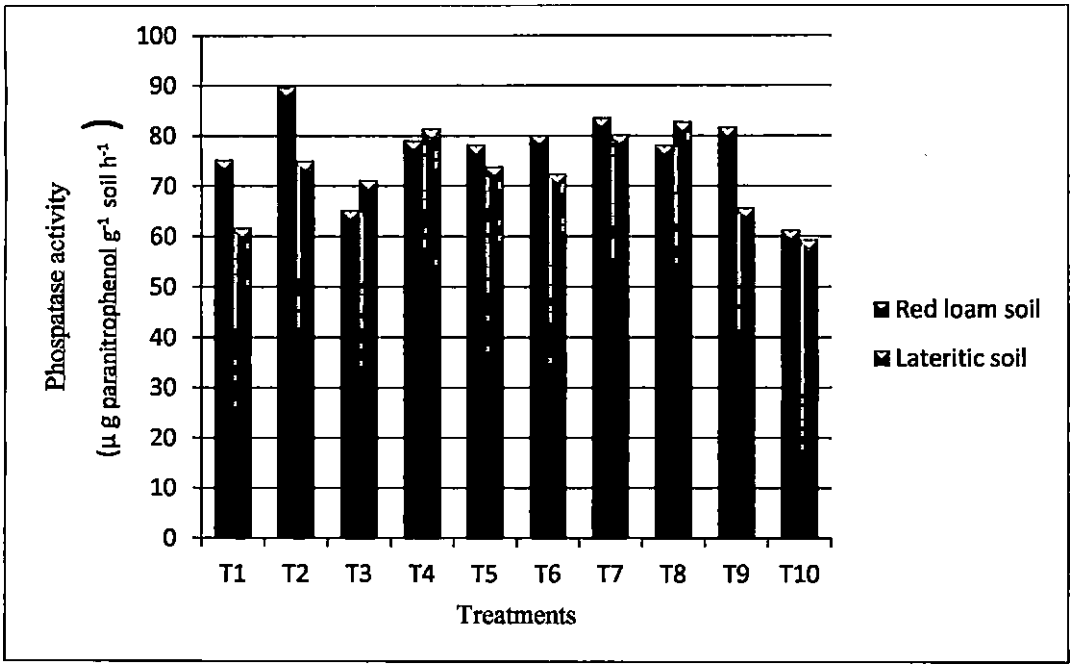


Fig.7. Effect of treatments on soil phospatase activity

Neem cake contains the alkaloids, nimbin and nimbidin, which inhibit the nitrification process in soil. Conversion of ammonium to nitrite was checked presumably by selective effects of neem cake on the ammonium oxidizing bacteria, *Nitrosomonas sp.* (Mishra *et al.*, 1975). Hence the accumulation of ammonia inhibits urease activity and this might be the reason for the inhibition of urease activity for treatment receving neemcake as the organic source for providing N compared to treatments receiving inorganic N in the form of urea.

5.2.3.2 Phosphatase

Phosphatases perform an important function in soil by transforming organic P to inorganic phosphate. Although organic P in soil accounts for up to 80 per cent of total soil P, it is considered to be unavailable to plants unless first mineralized by the action of phosphatases. In addition to the hydrolysis of soil organic P compounds, phosphatases take part in the hydrolysis and subsequent reuptake of P esters leaked from plant roots (Hayes *et al.*, 1999).

In red loam soil the highest value of phosphatase activity was noticed for the treatment T_2 (Urea+RP+WA) which supplied only K organically and in lateritic soil the treatment T_8 (OC+BM+WA) in which all the major plant nutrients were supplied through organic sources recorded the highest value. This might be due to the high organic P content in these manures, which might have triggered the microorganisms to produce more phosphatase enzyme.

As phosphatase activity had shown to be highly correlated with both microbial respiration and total biomass in soil (Frankenber 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.

Organic fertilization resulting in significant increase in the activity of phosphatase has been reported by Kalembasa and Kuzienska, (2011).

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

5.2.3.1 Dehydrogenase

Dehydrogenases are considered to exist in soil as integral parts of intact cells and are thought to reflect the total range of oxidative activities of soil micro flora. The treatment combination (T_6) (OC+RP+WA) which supplied both N and K in organic forms recorded the maximum values for dehydrogenase activity in both soils, this might be due to higher organic manure application which would have favoured more microbial populations and hence more enzyme activity. Dehydrogenase, being strictly an endocellular enzyme, its activity is directly related to the active microbial population. Haider *et al.,* (1991) observed an increased dehydrogenase activity due to neem cake application. Addition of organic sources act as a good source of carbon and energy to heterotrophs by which their population increased with an increase in enzyme activities. In addition to soil microorganisms, soil microflora, plants roots and plant residues undergoing varying degree of decay also contribute to this pool. The dehydrogenase activity has been linked with the levels of readily available organic C substrates in the soil (Fraser *et al.* 1994). Soils high in organic C may already have high dehydrogenase levels without additions of organic amendments. Krishnakumar *et al,* (2005) reported higher dehydrogenase activities with the application of FYM+ neemcake. Strong relationship between organic manure and ezyme activities were reported by Garcia *et al,* (2008) Kennady and Papendick (1995).

Dinesh *et al.,* (2000) reported higher dehydrogenase activity due to organic manure addition. The activity of dehydrogenases basically depends on the metabolic activity state of the soil biota. It is significantly correlated with soil biomass carbon in organic amended soil (Garciagill *et al.*, 2000).

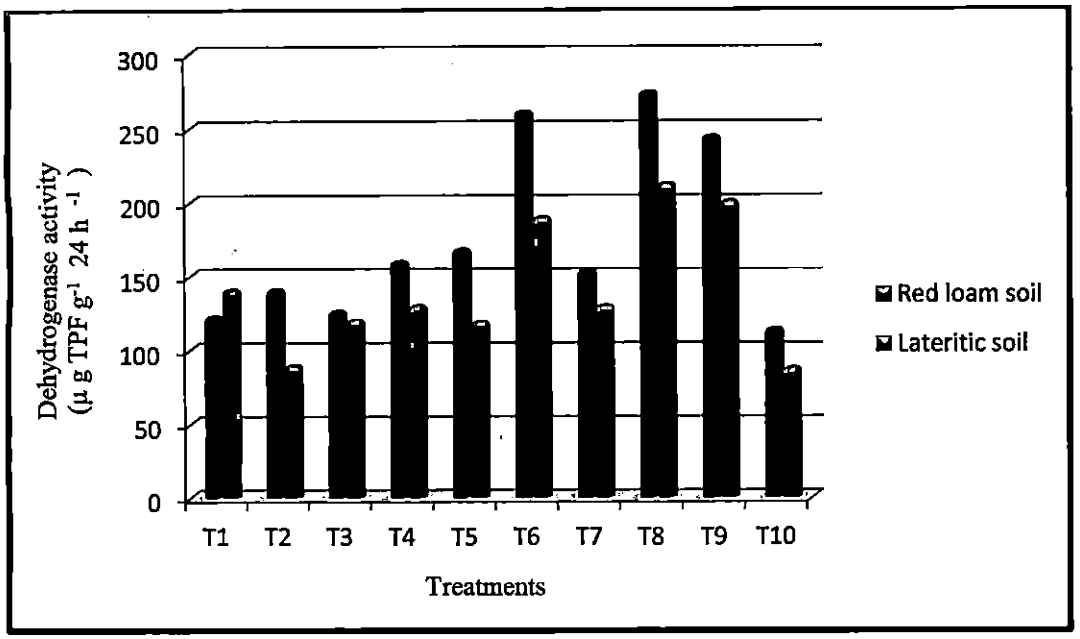


Fig. 8. Effect of treatments on dehydrogenase activity.

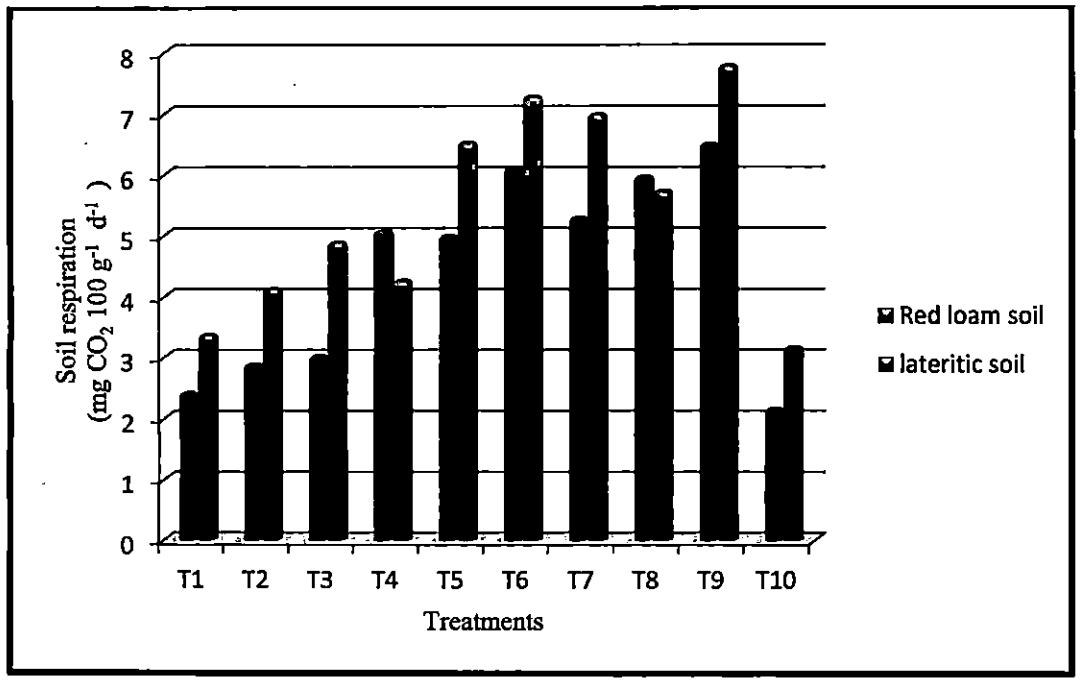


Fig. 9. Effect of treatments on soil respiration

5.2.4 Soil respiration

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 strong indicator of the soil metabolism and ecological soil functions. In both the soils T_9 the KAU organic POP treatment which included the combined application of vermicompost and poultry manure recorded the maximum values. The same treatment recorded the maximum populations of earthworm in both soils. Since earthworms constiute the maximum mega faunal population of any soil their abundance and consequently their respiratory activity may be the reason for the high CO_2 evolution rates measured in these soils. According to Kubat *et al.* (1999) organic fertilization contributes to soil organic matter accumulation and turn over in soils. Raupp and Lockretz (1997) reported that an increased soil organic matter turnover and accumulation enhances respiration activity in soils. Similar results were observed by Iovieno *et al.* (2009) in a study on soil respiration of two Mediterranean horticultural soils. Sposito and Zabel (2003) opined that a soil can be placed in the ideal activity class primarily for agricultural land uses if the soil respiration measured in that soil falls in the range 32 to 64 lbs CO_2 – C $acre^{-1}$ d^{-1} indicating an ideal state of biological activity.

5.2.5 Carbon mineralization potential

The carbon mineralization potential of the soils were estimated as the organic carbon contents of the soil. The treatments were significantly influenced by the various treatments as evidenced from the data presented in the Table 15 . It is inferred from the table that application of N alone in organic source and P and K as inorganic forms (T_5) recorded the maximum value in red loam soil. This was on par with KAU organic POP (T_9), the combined application of vermicompost and poultry manure which recorded the maximum value in lateritic soil also. This might be due to the direct incorporation of organic matter and better root growth. The practice of addition of organic manures for building up

organic carbon status of soil is well recognized and advocated and the results of the present study are also in conformity with the reports of several workers. Neem-amended soil maintained organic carbon at the pre-incubation level, whereas that in the control soil declined to significantly less than the pre-incubation concentration (Agbenin *et al.* 2008)

Studies on the influence of organics by Elayaraja and Singaravel (2011)on the soil nutrient availability in a coastal sandy typic Udipsamment revealed that application of coirpith compost @12.5 t ha^{-1} registered the highest organic carbon status followed by the application of poultry manure @12.5t ha^{-1}. Organic residue incorporation improving the soil nutrient pool in a gradual manner has been reported by Srivastava (1988), Bhat *et al.* (1991) and Pushpa (1996).

5.2.6 N mineralization potential

The treatments caused significant variation in available N content. In red loam soil T_6 (OC + RP +WA) which included N and K in organic form and P in inorganic form recorded the maximum N. The reason could be attributed to the fact that the addition of organic matter primarily provides nitrogen to the soil. The organically bound form of nitrogen becomes available in soil after decomposition, followed by mineralization into inorganic forms (Tusneem and Patrick, 1971), which in turn improves the available N content in soil. Slower release of N from neem cake might be due to its nitrification inhibition property. In addition to nutrients, neem cake contains the alkaloids, nimbin and nimbidin, which effectively inhibit the nitrification process in soil (Reddy and Prasad, 1985). Thus neem cake act as an immobilizer, thus conserving the applied and soil nitrogen and mineralizing steadily over a longer period.

The increase in available nitrogen is due to the enhanced mineralisation of organic matter as a consequence of high microbial activity. The process of aminisation, ammonification and oxidative deamination all brought about by

microbially mediated systems are believed to be active in organic sources treated medium, thus contributing more of soluble nitrogen to the soil.

Improvement of soil health as measured quantitatively using biological properties of soils as evaluatory tools

Table 19 depicts the improvement of soil health brought about by the application of the different treatments as measured quantitatively using biological properties of soil as evaluator tools in red loam soil and lateritic soil respectively. The relationship between various crop management practices and soil biological properties is well recognized though not well understood. Among the management practices nutrient application has the most direct link with soil biological properties of soils as the soil biota which are the pivotal agents for all the biochemical transformations in soil concerned with plant nutrition are largely determined by the type, form and quality of the nutrients added to the soil.

The present investigation was undertaken to study the changes the major biological properties of a soil undergo when the major nutrient requirements of a crop grown on it are met by different sources, viz organic, inorganic and their combinations, so that they can be employed as effective tools for evaluating the health of a soil. For this purpose the major biological properties of both soils quantitatively estimated before and after raising crops, supplying the major nutrients N, P and K in different forms as per the technical programme. To aid in meaningful discussion, comparison has been made between the initial status of each biological property and its final status as effected by treatments registering the highest value for that property, that treatment being designated as the best treatment for that property.

Both soils were absolutely devoid of earthworm populations initially. Treatment T_9 (KAU organic POP) which included application of vermicompost to soils could build up a population of 6.67 nos m^{-2} in red loam soil and 9.33 nos m^{-2} in lateritic soil. Reganold and Palmer (1995) who viewed earthworm population and weight as biological indicators of soil health suggested a population of 10 nos

m^{-2} of surface of soil for a good agricultural system. Soil respiratory activity, another sensitive and reliable soil biological activity reflecting the living dynamic nature of any soil was also maximum favoured by this treatment, the increase being 2,26 times in red loam soil and 1.96 times in lateritic soil.

In both soils the populations of arthropods consisting of the collembolan and mites were maximum enhanced by the treatment T_6 (OC+RP+WA) both N and K in organic forms and P alone in inorganic form, 4.25 times in red loam soil and 2.94 times in lateritic soil. The same treatment was responsible for building up the highest microbial populations in both soils. Bacterial populations increased 12.25 times, actinomycets population from 0 to 9.33×10^3 cfu g^{-1} soil and fungal population 3.38 times in the red loam soil , where as the resultant populations of these in lateritic soil were 9.36, 6.52 and 2.27 times respectively.

Urease activity increased 2.43 times in red loam soil and 2.70 times in lateritic soil by the same treatment T_4 (Urea+ BM+ WA) which is a combination of N in inorganic form and both P and K in organic forms. Phophatase activity increased 1.48 times in red loam soil as a result of T_2 application (Urea+RP+WA) which is combination of both N and P in inorganic forms and K alone in organic forms. In lateritic soil the maximum increase in phosphatise activity (1.57 times) was due to treatment T_8 (all major nutrients in organic form. The same organic combination treatment is responsible for maximising the dehydrogenase activity in both soils, 3.57 times in red loam soil and 2.57 times in lateritic soil.

Carbon mineralization potential increased 3.12 times in red loam soil as a result of T_5 application (OC+RP+MOP) which is a combination of N alone in organic form and P and K in inorganic forms where as it was 3.40 times in lateritic soil by treatment T_9 (KAU organic POP). N mineralization potential was maximum favoured by treatment T_6 (OC+RP+WA) in red loam soil (1.15 times) and T_1 (KAU POP) in lateritic soil.

Summary

6. SUMMARY

Biological properties of soils which respond quickly to even slight changes in soil environment are considered as more sensitive and reliable tools for evaluation of soil health than physical properties of soils which alter only after a drastic change in soil quality.

Among the management practices which profoundly influence the biological properties of soils, nutrient application has the most direct link as the soil biota is largely determined by the type, form and quantity of the nutrients added to soil.

The present investigation was an attempt to study the changes the major biologically properties of a soil undergo when the nutrient requirements of a crop grown on this are met by different sources, organic, inorganic and their different combinations, so that they can be employed as effective tools for evaluating soil health. For the purpose of comparison and for arriving at conclusive results two major soil types of Vellayani viz red loam and lateritic were used on each of which amaranthus was raised as the test crop. The treatments were combinations of organic and inorganic sources of the major plant nutrients N, P, K for supplying the nutrient requirement of this crop (50:50:50 kg N P K ha^{-1}) as per KAU, POP (2011)

Summarized below are the salient findings which are generated out of detailed investigations carried out at laboratory and field levels.

* The biometric observations *viz.*, plant height, number of leaves, number of branches, stem girth, root length and root volume were all significantly influenced by different treatments.

* For plant height the combination Urea+ BM+MOP which supplied both N and K in inorganic form and P as organic form recorded the maximum values in both soils and it was found to be on par with the treatment combinations OC+ RP +

MOP and Urea+BM+WA in red loam soil. In lateritic soil this was superior to all other treatments. The lowest value for plant height was noticed in control plot in both soils.

* Stem girth of plant was significantly influenced by different treatments in both soils. In red loam soil, Urea+ RP+MOP which is a combination of all major plant nutrients in inorganic sources recorded the highest mean value for stem girth while in lateritic soil the treatment Urea +RP+ WA , K alone as organic form recorded the highest mean value.

* Number of branches plant^{-1} was also significantly influenced by different treatments. In red loam soil the highest mean value was registered by the treatment combination Urea+ BM+MOP which was on par with KAU Org POP and OC + RP +WA. In lateritic soil the treatment OC+BM+WA registered the highest mean value and it was found to be on par with Urea+ BM+MOP and OC + RP +WA.

* Regarding root length, in red loam soil the combination of Urea+BM+WA recorded the maximum value while it was for the combination of Urea+RP+WA in lateritic soil. For root volume the combination of OC+BM+WA recorded the maximum value in red loam soil and Urea+ RP+MOP in lateritic soil.

* Significant differences were observed among yield attributing characters like leaf weight plant $^{-1}$, stem weight plant $^{-1}$, shoot biomass plant $^{-1}$, root biomass plant $^{-1}$, biomass yield plant $^{-1}$ and total yield plot $^{-1}$.

* For yield attributes like leaf weight plant $^{-1}$, stem weight plant $^{-1}$, shoot biomass plant $^{-1}$ and root biomass plant $^{-1}$ the combination of Urea+ RP+MOP recorded the maximum values in both soil.

* In both soils the combination of inorganic sources of plant nutrients which is the package of practice recommendation of KAU for amaranthus registered the maximum values for total yield plot^{-1}.

* Quality parameters of the produce like vitamin C content, protein content β-carotene content, oxalate content and nitrate content were also influenced by various treatments. In the case of vitamin C content and β-carotene content treatment combination OC+ RP+MOP which is a combination of N alone in the organic form with both P and K in the inorganic forms recorded the maximum values in both soils.

* For crude protein content, OC + RP +WA recorded the maximum value in red loam soil and it was on par with OC+ RP + MOP. In lateritic soil the highest mean value recorded by the treatment OC+BM+WA and was on par with OC+ RP + MOP.

* The control plot recorded the minimum values for nitrate content in red loam and lateritic soil. Oxalate content showed the least value for treatment KAU organic POP in red loam and for treatment combination which supplied all major nutrients in organic form in lateritic soil

* Soil biological indicators viz., soil mega and meso fauna, soil microflora, soil enzymes, soil respiration, C mineralization potential and N mineralization potential were all significantly influenced by different treatments.

* The treatment which included application of two organic sources of nutrients viz vermicompost and poultry manure (KAU org POP) registered significantly higher population of earthworm and soil respiratory activity in both soils.

* The treatment combination (OC + RP +WA) in which both N and K were applied through organic sources recorded highest population of athropods and soil microbial population (bacteria, actinomycetes and fungal)

* The treatment combination Urea+BM+WA which is a combination of N alone in inorganic form and both P and K in organic form recorded the maximum values for soil urease activity in both soils.

*With regard to the phosphatase activity the treatment combination Urea+RP+WA which supplied only K organically, recorded the maximum value in red loam soil. In lateritic soil the combination of OC+BM+WA in which all the major plant nutrients were supplied through organic sources recorded the highest value.

* In the case of dehydrogenase activity the treatment combination OC+RP+WA which supplied both N and K in organic forms recorded the maximum values.

* Regarding carbon mineralization potential application of N alone in organic source and P and K in inorganic forms recorded the maximum value in red loam soil. This was on par with KAU organic POP, the combined application of vermicompost and poultry manure which recorded the maximum value for carbon mineralization potential in lateritic soil .

* In red loam soil the combination of OC + RP +WA in which N and K were applied in organic forms and P as inorganic form recorded the maximum N mineralization potential while in lateritic soil the treatment combination Urea+ RP+MOP which supplied both N and K in inorganic form and P in organic form recorded the maximum value.

.*Economic analysis of various treatments showed that the combination of inorganic sources of plant nutrients (KAU org POP) generated the highest profit compared to all other treatments in both soils.

Based on a critical comprehensive appraisal taking into consideration all aspects of the crop including yield, quality soil health and benefit to the farmer the following conclusions can be drawn

For yield, treatment T_1 consisting of all major plant nutrients in inorganic forms (Urea+rock phosphate+ muriate of potash) which happens to be the package of practices recommendation of Kerala Agricultural University for amaranthus is definitely the best for both soils. The returns over investment was also maximum for this treatment.

For quality in terms of vitamin C, β carotene and crude protein content treatment T_5 (oil cake+ rock phosphate + Muriate of potash) which supplied only N organically was found to be the best as it recorded either the maximum values or values which were statistically on par with the highest value in both soils.

Regarding the biological properties of soils, treatment T_6 (oil cake+ rock phosphate+ wood ash) which is a combination of N and K in organic forms and P alone in inorganic form can be adjudged to be the best treatment as it registered significantly the highest values for characters like arthropod, bacterial, actinomycetes and fungal populations in both soils. For enzyme activities also the values registered by this treatment were on par with the highest values recorded.

Between the two soils the biological properties of the red loam soil were more favourably influenced by the treatments than the lateritic soil as evidenced by the improvement over the initial status of the soil that could be quantitatively measured.

Though more or less chemically identical the more loamy nature of the red loam soil with comparatively less gravel and sand permitting optimum aeration and moisture infiltration might have predisposed this soil to be a better receipt of the benefits of organic supplementation of plant nutrients.

FUTURE LINE OF WORK

Inspired by the results so far generated further investigations in the following lines are suggested

- Inclusion of other important biological properties of soils like microbial biomass C, N, P and S which could not be undertaken in this study
- Inclusion of inorganic nutrient sources like complex fertilizers and their foliar application

- Inclusion of organic nutrient sources like enriched composts, vermiwash etc
- Extrapolation of the results of the present study to other crops and soils

It is hoped that the results of the study will help in planning a judicious manurial schedule for amaranthus crop for obtaining high yield with jeopardizing soil health.

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BIOLOGICAL INDICATORS OF SOIL HEALTH AS INFLUENCED BY PLANT NUTRIENT SOURCES

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Abstract of the

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ABSTRACT

The research project entitled '**Biological indicators of soil health as influenced by plant nutrient sources** ' was undertaken to study the changes the major biological properties of a soil undergo when the major nutrients to a crop grown on it are supplied organically or inorganically or in their different combinations and to employ them as tools for evaluating the health of that soil. The investigations consisted of laboratory studies and two field trials at the Instructional Farm, College of Agriculture, Vellayani with Amaranthus var.Arun during May 2012 to July 2012 in two soil types of Vellayani, red loam and lateritic. The ten treatments were laid out in RBD with three replications. The treatments consisted of T_1 (Urea+ Rock phosphate+ Muriate of potash) (KAU POP, 2007), T_2 (Urea+ Rock phosphate+ Wood ash), T_3 (Urea+ Bone meal+ Muriate of potash), T_4 (Urea+ Bone meal + Wood ash), T_5 (Oil cake+ Rock phosphate+ Muriate of potash), T_6 (Oil cake +Rock phosphate +Wood ash) , T_7 (Oil cake+ Bone meal+ Muriate of potash) , T_8 (Oil cake+ Bone meal+ Wood ash), T_9 (KAU Organic POP, 2009), T_{10} (Control)

The biometric observations *viz.*, plant height, number of leaves, number of branches, stem girth, root length and root volume were all significantly influenced by different treatments. Significant differences were observed among yield attributing characters like leaf weight plant $^{-1}$, stem weight plant $^{-1}$,shoot biomass plant $^{-1}$, root biomass plant $^{-1}$, biomass yield plant $^{-1}$ and total yield plot $^{-1}$. The highest yield plot $^{-1}$ was recorded by the treatment combination T_1 in both soils.

With respect to quality characters the treatment combination T_5 recorded the highest value for vitamin C and β-carotene content in both soils. For crude protein content treatment T_6 recorded the highest value in red loam soil and T_8 in lateritic soil to both of which T_5 was on par. Oxalate content and nitrate content were also influenced by different treatments .T_9 registered significantly higher population of earthworm and soil respiratory activity in both soils. Soil microathropod and soil microbial population (bacteria, actinomycetes and fungal) were maximum in the treatment combination T_6.

In both soils urease activity was maximum for T_4 and dehydrogenase activity maximum for T_8, phosphatase activity showed maximum values for T_2 in red loam soil and T_8 in lateritic soil. Soil organic carbon and available N, P, K content in the soils were significantly influenced by various treatments. Regarding Carbon mineralization potential estimated as the organic C content of the soil T_5 recorded maximum value in red loam soil and T_9 in lateritic soil. The treatment combination T_6 registered highest values for nitrogen mineralization potential in red loam soil while T_1 for lateritic soil.T_7 recorded highest values for available P content in both soils and available K content in lateritic soil. Economic analysis of various treatments showed that the combination of inorganic sources of plant nutrients T_1 generated higher profit compared to all other treatments in both soils.

Taking into account the favourable effect exerted on biological properties of soil, yield and yield attributes treatment T_6 which is a combination of N and K in organic form and P in inorganic form to supply the recommended dose of major nutrients to the crop can be adjudged to be the best treatment for economic production of amaranthus in both red loam and lateritic soils of Vellayani. Considering quality of the crop treatment T_5 which supplied N alone organically was found to be best.

Appendix

APPENDIX I

Weather parameters during field experiment (May 2012 – July 2012)

Standard weeks	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Relative humidity (%)	Rain fall (mm)
20	31.5	26.1	91.4	22.0
21	31.5	25.8	91.7	0.0
22	31.5	26.1	90.0	1.0
23	31.3	24.7	91.4	3.6
24	30.4	23.9	93.6	7.0
25	29.4	24.3	94.4	3.5
26	29.8	23.8	87.0	6.0
27	29.5	23.9	95.1	7.4
28	29.6	24.0	88.9	7.9
29	30.3	23.5	92.3	5.3
30	30.1	25.1	94.4	5.8
31	30.2	24.6	94.0	0.0

APPENDIX II

Composition of media for microbial enumeration

1. Enumeration of Bacteria

Media: Nutrient Agar

Composition

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

3. Enumeration of Actinomycetes

Media: Kenknight's Agar

Composition

1. Dextrose - 1gm
2. KH_2PO_4 - 0.1 gm
3. $NaNO_3$ - 0.1 gm
4. KCl - 0.1 gm
5. $MgSO_4$ - 0.1 gm
6. Agar - 15gm

Distilled water - 1000 ml