ASSESSMENT OF SOIL HEALTH AND STATUS OF HEAVY METALS IN THE CERTIFIED ORGANIC FARMS OF KERALA

by

GREESHMA P. R.

(2017-11-022)

THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695 522

KERALA, INDIA

2019

DECLARATION

I, hereby declare that this thesis entitled **"ASSESSMENT OF SOIL HEALTH AND STATUS OF HEAVY METALS IN THE CERTIFIED ORGANIC FARMS OF KERALA"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

Vellayani

Date: 28/09/2019

Greeshma

Greeshma P. R.

(2017-11-022)

CERTIFICATE

Certified that this thesis entitled **"ASSESSMENT OF SOIL HEALTH AND STATUS OF HEAVY METALS IN THE CERTIFIED ORGANIC FARMS OF KERALA"** is a record of research work done independently by Ms. Greeshma P.R. (2017-11-022) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani

Date:

Dr. Usha Mathew
(Major Advisor, Advisory Committee)
Professor
Department of Soil Science & Agricultural Chemistry
College of Agriculture, Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Greeshma P. R.** (2017-11-022) a candidate for the degree of **Master of Science in Agriculture** with major in **Soil Science and Agricultural Chemistry**, agree that the thesis entitled "Assessment of soil health and status of heavy metals in the certified organic farms of Kerala" may be submitted by **Ms. Greeshma P. R.** (2017-11-022), in partial fulfilment of the requirement for the degree.

28/09/2019

Dr. Usha Mathew
(Major Advisor, Advisory Committee)
Professor
Department of Soil Science &
Agricultural Chemistry
College of Agriculture, Vellayani

28/09/2019

Dr. K. Ushakumari
(Member, Advisory Committee)
Professor and Head
Department of Soil Science &
Agricultural Chemistry
College of Agriculture, Vellayani

28/9/19

Dr. Biju Joseph
(Member, Advisory Committee)
Assistant Professor
Department of Soil Science &
Agricultural Chemistry
Instructional Farm
College of Agriculture, Vellayani

28/9/19

Dr. Ameena M.
(Member, Advisory Committee)
Assistant Professor
Department of Agronomy
College of Agriculture, Vellayani

ACKNOWLEDGEMENT

I wish to express my sincere gratitude and indebtedness to **Dr. Usha Mathew**, Professor and Major Advisor, Department of Soil Science and Agricultural Chemistry, for formulating the research problem, her sustained enthusiasm and support during the investigation and her valuable guidance and suggestions in preparation of the thesis.

I am indebted to **Dr. K. Ushakumari,** Professor and Head, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani, and member of Advisory Committee, for her valuable advice, extreme patience and whole hearted approach for the successful completion of the thesis.

I am extremely thankful to **Dr. Biju Joseph,** Assistant Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture Vellayani, and a member of Advisory Committee for the support, constant criticism and valuable suggestions rendered throughout the period of research work and course of study

With great pleasure, I express my gratitude to **Dr. Ameena M.,** Assistant Professor, Department of Agronomy, College of Agriculture, Vellayani and a member of Advisory Committee for her encouragement, wholehearted help and support throughout the period of my research work.

My heartiest and esteem sense of gratitude and indebtedness to **Dr. Sudharmaidevi,** Professor and Head, (Retd.) Department of Soil Science and Agricultural Chemistry, **Dr. Manorama Thampatti**, Professor, Department of Soil Science and Agricultural Chemistry and other teachers of Department of Soil Science and Agricultural Chemistry for all the necessary help extended to me in the fulfilment of this work.

I am extremely thankful to **Mr. Joykutty Vincent**, Secretary, ICS organic farming group, Kannur, **Dr. Mathew Mathew** and **Mr. Thomas Mathew**, Palakkad, **Mr. P.J. Chackochan**, Vanamoolika, Wayanad and all other respondents of survey *and the workers for their kind help in availing the basic resources for conducting this study in Kannur, Palakkad and Wayanad districts.*

I take this opportunity to acknowledge my post graduate batch mates, my seniors and all the staff members of the Department of Soil Science and Agricultural Chemistry for their constant support and encouragement during the course of this investigation.

I am also indebted to my friends of other departments for their constant inspiration and support rendered to me in the fulfilment of this work.

I thankfully remember the services rendered the staff members of College of Horticulture and Vytila rice research station in completing my chemical analysis.

I am thankful to Kerala Agricultural University for the technical and finanacial assistance for conducting this work.

This work would never have been possible without the encouragement and support of my family to whom I extend my heartfelt gratitude.

Greeshma P R

CONTENTS

LIST OF TABLES

23.	Comparative evaluation of the effect of organic and conventional farming on available Cd, mg kg^{-1}	49
24.	Comparative evaluation of the effect of organic and conventional farming on available Pb, mg kg^{-1}	49
25.	Comparative evaluation of the effect of organic and conventional farming on available Ni, mg kg^{-1}	50
26.	Comparative evaluation of the effect of organic and conventional farming on dehydrogenase activity, µg of TPF g^{-1} soil 24 h^{-1}	50
27	Comparative evaluation of the effect of organic and conventional farming on respiratory activity, mg CO_2 100 g^{-1} soil 24 h^{-1}	51
28	Comparative evaluation of the effect of organic and conventional farming on bacteria count, log cfu/ml	51
29	Comparative evaluation of the effect of organic and conventional farming on fungi count, log cfu/ml	52
30	Comparative evaluation of the effect of organic and conventional farming on actinomycetes count, log cfu/ml	52
31	Comparative evaluation of the effect of organic and conventional farming on earthworm and arthropod population, number m^{-3}	53
32	Soil quality index of soils, per cent	53
33	Heavy metal content (Zn, Cu and Ni) in inputs	56

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVATIONS

Avail.	:	Available
As	:	Arsenic
B	:	Boron
BD	:	Bulk density
Ca	:	Calcium
Cd	:	Cadmium
Cfu	:	Colony forming unit
cm^{-3}	:	Per cubic centimetre
CO_2	:	Carbon dioxide
COC	:	Copper oxy chloride
Cr	:	Chromium
Cu	:	Copper
$dS\ m^{-1}$	:	Deci Siemens per metre
EC	:	Electrical conductivity
EFY	:	Elephant Foot Yam
et al.	:	Co-workers/ Co-authors
Fe	:	Iron
Ferti.	:	Fertilizers
FYM	:	Farmyard manure
Fig.	:	Figure
g	:	Gram
GM	:	Green manure
h^{-1}	:	Per hour
ha^{-1}	:	Per hectare
HCl	:	Hydrochloric acid
$HClO_4$	:	Perchloric acid
Hg	:	Mercury
HNO_3	:	Nitric acid

i.e.	:	That is
K	:	Potassium
KAU	:	Kerala Agricultural University
kg^{-1}	:	Per kilogram
L	:	Litre
m^{-2}	:	Per square metre
m^{-3}	:	Per cubic metre
mg	:	Milligram
Mg	:	Magnesium
Mg m^{-3}	:	Mega gram per cubic metre
mm	:	Millimetre
Mn	:	Manganese
mL	:	Millilitre
M ha	:	Million hectare
N	:	Nitrogen
Ni	:	Nickel
NPOP	:	National Programme for Organic Production
No.	:	Number
P	:	Phosphorus
Pb	:	Lead
pH	:	Potenz hydrogen
S	:	Sulphur
SOC	:	Soil Organic Carbon
SOM	:	Soil organic Matter
SQI	:	Soil Quality Index
t	:	Tonnes
TPF	:	Triphenyl formazan
VAM	:	Vesicular Arbuscular Mycorrhizae
viz.,	:	Namely
WHC	:	Water Holding Capacity
Zn	:	Zinc

LIST OF SYMBOLS

%	:	Per cent
@	:	at the rate of
ºC	:	Degree Celsius
µ	:	Micro
₹	:	Rupee
*	:	Significant

Introduction

1. INTRODUCTION

Green revolution considerably reduced world food shortage but at a high environmental cost. Intensive agriculture and indiscriminate use of agrochemicals led to poor soil fertility and destruction of useful microbes and there was an increased demand for more fertilizers for getting the same yield. These, not only led to land degradation but also affected the quality and taste of agricultural produce and hence increased the health and environmental risks. Organic farming helped in mitigating many of these problems. It aims in long term sustainability. Organic farming is gaining momentum in the country in the past few years owing to the belief of its ability to supply safe or poison free food as well as reduced environmental pollution.

Soil health also referred to as soil quality can be defined as the capacity of soil to perform within ecosystem boundaries to sustain biological productivity, maintain environment quality and promote plant and animal health (Doran and Parkin, 1994). Soil quality may not be directly measured, but may be inferred from measurable soil properties termed as soil quality indicators (Acton and Padbury, 1993). It depends on soil texture, structure, soil reaction, electrical conductivity, water holding capacity, organic matter content, nutrient status, mineralogical composition, CEC, drainability and many other properties. Organic farming encourage and enhance biological cycles within farming systems to maintain and increase long term fertility of soil and use as far as possible renewable resources for these purposes.

Kerala state enjoys a tropical monsoon climate congenial for high biomass activity manifested by rich biodiversity. However, the soil and land resources of the state are confronted with many problems and now Kerala is shifting to eco-friendly farming practices reducing the use of chemicals and fertilizers realising the problems of using chemicals (Soumya, 2016). So in this context, the present soil quality status of soil of farms following organic system will be useful. But studies focusing on the long term evaluation of soil quality of organic farms of Kerala is scarce.

Heavy metals are considered as the most toxic pollutant as it is impossible to eradicate it from the environment as against pesticides which can be either removed or degraded to less toxic or non-toxic products (Alloway, 1990). Metals having a density higher than 5 Mg m^{-3} are considered as heavy metals. Some heavy metals like Zn, Cu, Ni, Fe and Mn are considered as essential plant nutrients, even though they are phytotoxic at higher concentrations. Other metals like Pb, Cd, Hg, Cr and As are toxic even at low concentrations. Heavy metals enter agricultural land through natural and anthropogenic sources.

In organic farming, even though synthetic fertilizers and pesticides are not allowed, large quantities of organic manures are applied to satisfy NPK requirement of crops. Animal manures and sewage sludge (bio-solids) are the main organic fertilizers and the latter may also contain heavy metal contaminants (Mortvedt, 1995). Heavy metal concentration in certain organic manures recorded by Park *et al.* (2010), were as follows: Cow dung – 200 mg kg^{-1} Cu, 700 mg kg^{-1} Mn, 800 mg kg^{-1} Zn, Cow manure – 6.8 mg kg^{-1} As, 0.7 mg kg^{-1} Cd, 2.23 mg kg^{-1} Co, 17.5 mg kg^{-1} Cu, 172 mg kg^{-1} Mn, 9.6 mg kg^{-1} Ni, 7.5 mg kg^{-1} Pb ; Poultry dropping – 450 mg kg^{-1} Cu , 1800 mg kg^{-1} Mn, 2300 mg kg^{-1} Zn. Content of heavy metals like Cd, Pb and Ni in vermicompost, sewage sludge, and FYM from cattle fed with fodder from sewage farm were reported to be in the range of 2.2-7.2, 3.1-54.4 and 5.5-17.4 mg kg^{-1} respectively (Mathew, 1999).

So, there is a chance of accumulation of heavy metals in soil as well as in plant produce of organic farming depending on plant's ability to absorb them and also various other factors like climatic conditions, organic manure used. Even though content of toxic heavy metal in organically grown crops was found lower in certain previous studies conducted in various parts of world, the effect has to be studied in Kerala condition. Studies have to be conducted to ascertain whether the organic produce are contaminated by or free from heavy metals.

In order to be a certified organic farm, crops must be grown on land, free of prohibited substances continuously for at least three years. National organic standards require producers to use organic agricultural methods and materials that cover soil fertility, the application of manure, crop rotation and composting and to control pest and diseases also there is list of materials that can be used. But these are very difficult to be followed as farmers are concerned more of monetary benefits and the availability of quality organic manure is limited. So, to what extent the beneficial effects are translated to soil health and quality of produce of certified organic farms following organic practices in terms of heavy metal content have to be validated.

In this context, the present study has been planned with following objective:

- To assess and compare the soil health parameters and heavy metal status of the inputs and produce of certified organic farms and conventional farms.

Review of Literature

2. REVIEW OF LITERATURE

Organic farming is gaining momentum in the country in past few years. Organic system of farming is claimed to be a sustainable system which helps in improving soil quality and in reducing environmental risks. This chapter attempts to review the available literature on physical, chemical and biological properties that are indicators of soil health of organic and conventional farms and also heavy metal content in crop produces as well as inputs used in organic and conventional systems of farming.

2.1. SOIL HEALTH PARAMETERS OF ORGANIC AND CONVENTIONAL FARMS

2.1.1 Physical properties

Reganold (1988) after studying the long term impact (nearly 40 years) of organic and conventional farming soils in adjacent farms of Washington reported that in general physical properties of soils under organic farming are better than that of soils under conventional farming and specifically, water holding capacity is significantly higher in organic whereas no significant difference was noticed in case of bulk density.

A four year study conducted by Reganold *et al.* (1993) in adjacent biodynamic and conventional fields (total- 16 fields) in New Zealand revealed that bulk density was significantly lower on the biodynamic farms than their conventional counterparts. Bulk density is related to mechanical impedance and soil structure, which in turn affect root growth.

Liebig and Doran (1999) on analysing soil properties of top 30.5 cm soil on 5 pairs of farms in Nebraska, USA reported that in four out of five locations, bulk density was found to be significantly lower and water holding capacity significantly higher in organic than in conventional soil.

In contrast to this Colla *et al.* (2000) reported that there was no significant difference in bulk density as well as water holding capacity between organic and conventional plots of California.

Radhakrishnan *et al.* (2006) reported that a significantly higher water holding capacity and porosity were noticed in soils of biodynamic system followed by organic system than soils of conventional system when soils of tea estates of Nilgiris was analysed. Bulk density was also found to be lowest in case of biodynamic followed by organic and highest in case of conventional soils.

Soil bulk density and porosity were found lower and higher respectively, in the organic system than in conventional system after three years of management in organic and conventional farming (Araujo *et al.,* 2009).

Lowest bulk density was recorded when compost application was done whereas highest values were obtained when mineral fertilizer was applied (Celik *et al.,* 2010).

However no significant differences was observed between organic and conventionally managed soils for any of the soil physical properties measured when sixteen pairs of farms, throughout England were analysed (Hathaway-Jenkins *et al*., 2010).

Ramesh *et al.* (2010) surveyed certified organic farms and nearby conventional farms of 5 states of India and on analysis of 300 soil samples reported that on an average, in Indian organic soils bulk density is lower than conventional soils and particularly in Kerala (30 soil samples analysed) bulk density was found to be lesser in organic soils.

No significant difference was noticed in bulk density and water-holding capacity in organic and conventional systems of elephant foot yam (EFY) field in Thiruvananthapuram, Kerala when examined after 3 years. However, bulk density was slightly lower and water-holding capacity slightly higher in organic plots. But at the end of 5 years, the water-holding capacity was found to be significantly higher in organic field (14.11%) than in conventional field (10.99%) (Suja *et al*., 2012).

Suja (2013) also claimed short-term responses of soil physical properties are variable as no significant differences was noticed in bulk density and water holding capacity between soils of organic and conventional field where yams and EFY was cultivated for 5 years except for WHC of soils where EFY was cultivated.

Velmourougane (2016) evaluated the long-term (12 years) impacts of organic and conventional methods of coffee farming in Kodagu district, Karnataka on soil properties at two depths of 0–15 and 15–30 cm and reported that water holding capacity (WHC) of the soil at 0–15 cm of organic system was found to be significantly higher by 53.36% compared to conventional system (45%), while WHC of organic and conventional system at 15–30 cm depth was found to be non-significant.

Sihi *et al.* (2017) concluded that soil physical properties were significantly improved after long term (about 15 years) organic cultivation compared to chemical fertilization when impact of organic vs. conventional cultivations of basmati rice on soil health at Kaithal district of Haryana was studied. Bulk density was found to be significantly lower (1.26 and 1.31 g cm^{-1} in organic and conventional farming, respectively) and water holding capacity was significantly higher (32 and 28 g cm^{-1} in organic and conventional farming, respectively) in organic system compared to conventional system. Similarly bulk density was found to be significantly lower in organic system only at 0–15 cm depth.

A positive influence was noticed in bulk density as well as in water holding capacity in organically managed soils (13 years) of Delhi in 0-15 cm and 15-30 cm soil layer and porosity was found highest in soil where *Sesbania* green manuring+ FYM + blue green algae for rice and *Leucaena* green leaf manuring + FYM + *Azotobacter* for wheat was applied and lowest when the field was unfertilized and when NPK fertilizers alone were used (Kaje *et al.*, 2018).

2.1.2. Chemical properties

2.1.2.1. Electrochemical properties of soil

A significantly higher pH was observed in conventional farms than biodynamic farms (Reganold *et al.*, 1993).

According to Liebig and Doran (1999), soil pH was found to be closer to neutral on organic farms at all five locations, with pH values significantly higher on organic farms at two locations.

Ramesh *et al.* (2010) observed there was a slight increase in pH and electrical conductivity in organic soil than in conventional soil. In Kerala soils, pH was found to be 5.96 and 5.64 and electrical conductivity 1.74, 1.18 dS m^{-1} for organic and conventional soil respectively.

Suja (2013) found there was significant increase in pH (0.46 to 0.77 unit increase) for organic soils where yam and EFY were cultivated.

Velmourougane (2016) reported that the electrical conductivity as well as pH was significantly higher in conventional systems at both depths (0-15 cm and 15-30 cm depth).

Sihi *et al.* (2017) claimed that a significant lowering of soil pH (about 0.5 units lower than conventional) in organic fields. A near neutral pH was observed in organic fields. Also, sa significantly higher EC values found in conventional fields was attributed to the excessive salts accumulations due to chemical fertilizer usage.

2.1.2.2. Available primary nutrients

Mean available P was found significantly higher in conventional farms than organic farms whereas mean minerlizable N was significantly higher in organic system and no significant difference was noticed in case of available K (Reganold *et al.*, 1993).

Compared to the conventional system, organic and low-input corn systems showed significantly higher surface soil mineral N levels during a cropping season (Poudel *et al.*, 2002).

Gosling and Shepherd (2005) reported that the concentrations of extractable potassium and phosphorus were found to be significantly lower in soils managed organically.

Panwar *et al.* (2010) on analyzing soils under organic, integrated and inorganic management of Bhopal reported that total mineral N was recorded highest in organic system followed by integrated system and then inorganic system at 0-15 cm and 15- 30 cm depth. Available K was found to be highest in soil of organic farm (277 mg kg^{-1}) followed by soil following integrated management (267 mg kg^{-1}) and then in inorganic system (256 mg kg^{-1}) at 0-15 cm depth and at 15-30 cm depth, its contents were 205 mg kg^{-1}, 188 mg kg^{-1} and 170 mg kg^{-1} in organic, integrated and inorganic soil respectively.

Ramesh *et al.* (2010) reported soils under organic management were having a higher available N, P and K when average of soils of 5 states were considered. Similar is the case with Kerala and in Kerala organic soils were found to have 244.4, 16.61 and 337 kg ha^{-1} N, P and K respectively and 209.1, 13.52 and 314.7 kg ha^{-1} N, P and K respectively in case of soils under conventional management.

Except for potassium in field where yam is cultivated no significant difference was noticed between organic and conventional fields. Also, phosphorus was found to be more in conventional field than organic field (Suja, 2013).

Velmourougane (2016) reported that available P and K was significantly higher in organic soil at both the depths (0-15 and 15-30 cm) whereas available N showed significance only at 0–15 cm. Also, it was observed that available N was found to be more in 15-30 cm than in 0-15 cm in conventional farms.

According to Sihi *et al.* (2017), significantly higher quantity of available N, P and K observed in organic field was due to the addition of organic residues to soil over long time.

2.1.2.3. Available secondary nutrients

Available Ca was found to be significantly higher in soils under organic management than in soils under conventional management. But no significant difference was found in Mg content (Clark *et al.,* 1998).

Available Ca and Mg were found to be significantly higher in soils amended with organic manures than soils amended with chemical fertilizers. The increase was almost two-fold over the 2-year period whereas only slight increase were observed in soils amended with synthetic fertilizers over the same time period (Bulluck *et al.,* 2002).

Liu *et al.* (2007) reported that soil of organic and sustainable farms of North Carolina, USA was found to have significantly higher levels of exchangeable Ca and Mg.

Suja *et al.* (2012) reported that no significant difference was noticed between organic and conventional field in case of exchangeable Ca and the value was about 813 and 659 kg ha^{-1} for organic and conventional soils respectively and the value of exchangeable Mg was about 39.7 and 28.7 kg ha^{-1} for organic and conventional field respectively and it differed significantly.

Soil samples from organic and conventional apple, pear, blackcurrant, carrot, beetroot, and celery growing areas in Poland, when analysed for available Ca, Mg and S showed a higher Ca content in conventional fruit plantation soils than organic. But organic vegetable fields were found to have higher Ca than conventional fields. The mean Mg level was found higher in organic than for the conventional blackcurrant plantation and for beetroot, conventional field recorded higher value. Available S was found twice as high in the conventional celery soils than in the organic soil. No differences were found in available S for the soils of remaining crops (Domagała-Świątkiewicz and Gastol, 2013).

2.1.2.4. Available micronutrients

Available B as well as available Mn increased over time in soils amended with cotton-gin trash or hay manure compost or yardwaste, but no change and a decrease in their content respectively were noticed in case of soils amended with synthetic fertilizers (Bulluck *et al.,* 2002).

Blaise *et al.* (2004) reported organic cotton cultivated soils of Nagpur have significantly higher micronutrient content (Zn, Cu and Mn) except Fe than conventional soils.

Soils managed organically were found to have significantly higher Fe, Mn, Zn, and Cu content than conventionally managed but on par with integrated managed system and available micronutrient content declined with depth (Panwar *et al.* 2010).

Ramesh *et al.* (2010) noticed that, on an average, soils under organic management were having higher micronutrient content than soils under conventional management in soils sampled across India as well as in Kerala. In Kerala, soils under organic management were found to have 2.58, 4.62, 46.8, 43.7 ppm Zn, Cu, Fe and Mn respectively and for soils under conventional management 1.47 ppm Cu, 2.95 ppm Fe, 32.57 ppm and 34.53 ppm Mn.

After five years of continuous cropping, available Fe, Cu and Mn was found to be significantly higher in organic field than in conventional field and the value of Cu, Mn, Fe in conventional soil was reported to be 1.5, 8, 59.6 ppm respectively and for organic soil 3.6, 17.4, 77.2 ppm respectively. Even though available Zn was not significantly different, it was found to be slightly more in organic plot (Suja *et al.*, 2012).

Available B was found in traces in soils of orchard in both organic and conventional management whereas in soils where vegetables were grown, higher available boron was found in fields under conventional cultivation (Domagała-Swiątkiewicz and Gastol, 2013).

All micronutrients were found to be significantly higher in organic soils than in conventional plots (Sihi *et al.*, 2017).

A significant increase was noticed in Zn, Cu, Fe and Mn in organic soil than in conventional soil of Haryana. Available Zn, Fe, Cu and Mn was 1.9, 11.38, 1.28 and 5.24 mg kg^{-1} in organically managed soil and 1.32, 9.38, 1.19, 4.95 mg kg^{-1} in conventionally managed soils respectively (Sheoran *et al.*, 2018).

2.1.2.5. Heavy metal

According to Nicholson *et al.* (2003), atmospheric deposition, manures and sludge are the most important sources of lead in agricultural soils.

Soil samples from organic farms showed significantly lower concentration of Cr, Ni, and Pb than those from conventional farms, whereas Cu and Zn were found more abundant in soils from organic farms. Cadmium concentration did not show any significant difference between soils of organic and conventional farms (Zaccone *et al.*, 2010).

Available heavy metals like Cr, Ni, As and Pb were found to be three-fold higher in soils of conventional farms than organic farms (Padmavathy and Poyyamoli, 2011).

No significant differences was noticed in the concentrations of available Cd and Pb, between soils under organic and conventional management when soils from different organic and conventional fields were analysed in Poland (Domagała-Swiątkiewicz and Gastol, 2013).

The Co, Cr, Cu, Fe, Mn and Ni were found to be higher in soils of conventional farms than organic farms. Similar level between two systems was recorded in the case of Cd and Pb were reported to be of same level in two systems, while Zn (65.5 mg kg^{-1}) was found to be much higher in soil of organic farm compared to conventional one (23.3 mg kg^{-1}) (Głodowska and Krawczyk, 2017).

2.1.3. Biological properties

2.1.3.1. Soil organic matter

After 8 years of continuous cultivation, soil total C in the organic and low input systems was found to be 23 and13% higher respectively, than conventional system (Clark *et al.,* 1998).

Fliessbach and Mader (2000) reported that long term management practices significantly affected the labile pool of soil organic matter.

In a permanent manurial trial in rice using PTB 20 at RARS Pattambi, Kerala during 1961-1999, it has been found that highest increase in yield was when FYM alone was applied and highest yield reduction when fertilizers were used alone. In case of SOM, highest SOM was recorded was when FYM+ GM+NPK fertlizers applied together (Mathew *et al.,* 2000).

Soil organic matter was found to be significantly higher in soils managed with alternative amendment (either cotton-gin trash, hay manure compost or yardwaste) which is about 2.83 per cent than in soils under conventional management (2 per cent) (Bulluck *et al.,* 2002).

Gosling and Shepherd (2002) reported no significant difference in soil organic matter content between organically and conventionally managed soil when 19 paired organic and conventional soils of Southern England were analysed. Hathaway-Jenkins *et al.* (2010) obtained a similar result.

Pulleman *et al.* (2003) after comparing SOM in a pair of organic and conventional fields found that SOM content was significantly higher in organic field than conventional field and when averaged across the upper 20 cm of the soil, organic soil contained 1.6 times more SOM (24 g kg^{-1}) than conventional soil (15 g kg^{-1}).

In a Farming System Trial conducted by The Rodale Institute, it has been found that after 22 years a significant increase was observed in soil carbon in the organic manure system, followed by the organic legume system than the conventional system. Soil carbon increase was about 27.9, 15.1, and 8.6% in the organic animal, organic legume, and conventional systems, respectively (Pimentel *et al.*, 2005).

Radhakrishnan *et al.* (2006) also reported there is significant increase in SOM in organic farms than in conventional soil and he concluded that this was the reason for stable soil aggregate formation and reduced bulk density of soil under organic management.

After three years of implantation of farming systems, SOC content were found 20.5, 15.5 and 7.2 g kg^{-1} in the organic, soil in native vegetation and conventional respectively (Araujo *et al.,* 2009).

Soil receiving manure recorded highest organic matter content at 0-15 and 15-30 cm depth (2.86% and 2.61%), followed by soil receiving compost (2.20% and 2.06%) and soil receiving mycorrhiza-inoculated compost (2.05% and 1.95%) respectively. However, no statistically important effect was observed on organic matter accumulation in soils when mineral fertilizers were used (Celik *et al.,* 2010).

Soils of organic farm was found to have higher mean soil organic matter (2.02 per cent) than soils of conventional farms (1.75 per cent) (Domagala-Swiątkiewicz and Gastol, 2013).

Sihi *et al.* (2017) claimed that the long-term addition of organic residues by the organic system plays a major role in SOM levels build up over time as SOM content was found to be significantly higher in organic soils.

2.1.3.2. Microbial biomass carbon

Microbial biomass carbon (fumigation extractable carbon) was found to be significantly higher in the organic and low-input systems than in conventional systems (Gunapala and Scow, 1998).

Mader *et al.* (2002) reported that soil microbial biomass was highest for soils under biodynamic agriculture followed by bioorganic, conventional system in which FYM was also used and then conventional system with mineral fertilizer alone in a 21 year DOK trial in Switzerland.

Microbial biomass carbon did not show any consistent significant difference under different management systems (Shannon *et al.*, 2002).

Soil of organic field exhibited a significantly higher microbial biomass carbon than conventional field despite the variations in time of samplings (3 seasons) (Marinari *et al.*, 2006).

2.1.3.3. Microbial count (Fungi, Bacteria, Actinomycetes)

Bacterial, fungal as well as actinomycetes count were found to be highest in biodynamic system followed by organic and then conventional systems (Radhakrishnan *et al.*, 2006).

Suja *et al.* (2012) reported that no significant difference was noticed in microbial count between organic and conventional soils after 5 years of continuous cropping. No significant difference was noticed between population of bacteria and fungi in organic and conventional fields (short term impact) of both crops tested, but actinomycetes was found to be significantly higher in conventional yam fields (Suja, 2013).

Velmourougane (2016) found significantly higher bacterial count in organic farms at 0-15 cm depth and no significant difference was noticed in population of fungi and actinomycetes in 0-15 and 15-30 cm depth and bacterial population in 15-30 cm depth although population was found to be more in organic than in conventional fields.

Sheoran *et al.* (2018) reported that the average populations of bacteria, fungi and actinomycetes in soils under organic management at different locations were 56.9 per cent, 55.2 per cent and 49.5 per cent higher than their conventional counterparts.

2.1.3.4. Earthworm count

In biodynamically managed soil, average 175 earthworms m^{-2} and in conventionally managed field 21 earthworms m^{-2} was found. By mass, 86.3 and 3.4 g earthworms per square meter was found in biodynamic and conventional systems respectively (Reganold *et al.*, 1993).

Pfiffner and Mäder (1997) on comparing the earthworm populations of organic, conventional and control plots during a long term trial in Switzerland found that earthworm populations were significantly higher in organic farming than in conventional or unfertilized farms. Similar result was obtained by Liebig and Doran (1999).

Earthworm abundance and biomass were found to be 2.1-3.3 times higher in organic fields than in conventional fields (Padmavathy and Poyyamoli, 2011).

According to Rai *et al.* (2014), inorganic fertilizer caused a negative impact on earthworm population whereas organic fertilizer promoted earthworm growth and reproduction.

2.1.3.5. Arthropod count

On an average, predators and parasitoids were more than 75 per cent and natural enemies 80 per cent in organic farms than in conventional fields (Drinkwater *et al.*, 1995).

Pfiffner and Niggli, (1996) on comparing organic, biodynamic and conventional systems of Switzerland reported that the bio-dynamic plots contained 193 per cent and organic plots 188 per cent higher epigaeic arthropods than conventional plots (100 per cent). The activity as well as density of carabids, staphylinids and spiders was reported to be higher in the bio-dynamic and the organic systems than in the conventional plots.

Soils managed under organic manure and organic legume system had greater populations of spores of AM fungi and greater colonization of plant roots than in the conventional system (Pimentel *et al.*, 2005).

On counting the epigaeic arthropods it have been found that average density of staphanylinids and spiders in the organic plots were almost twice that of conventional fields (Padmavathy and Poyyamoli, 2011).

Simoni *et al.* (2013) on examining an old organic field, young organic field and conventional maize fields in Italy reported that the arthropod density ranged from about 20,000 numbers m^{-2} in old organic to about 45,000 numbers m^{-2} in young organic. The number of oribatid mites was found higher in conventional than in old organic fields, while young organic field showed the highest density of collembolans.

The organic system recorded significantly higher (31.4%) total micro and macro fauna population compared to conventional system (Velmourougane, 2016).

Higher abundance and richness of soil arthropods were found in the organic farms than the conventional system in sugarcane fields of Brazil (dos Santos *et al.*, 2017).

2.1.3.6. Soil respiration

Reganold *et al.* (1993) claimed that respiration was significantly higher for biodynamic farms (73.7µl O_2 h^{-1} g^{-1}) than conventional farms (55.4 µl O_2 h^{-1} g^{-1}).

Wander *et al.* (1994) demonstrated that soil respiration was 50 per cent higher in the organic manure system than the conventional system after 10 years of the Rodale Institute farming system trial.

In clayey soils, the basal respiration was reported to be higher in organic soils than in the conventional soils, but in sandy soils there was no difference in respiration between organic and conventional soils (van Diepeningen *et al.*, 2006).

A significantly higher soil respiration was noticed in 0-15 cm depth of organic (29.3 mg CO_2 50 g^{-1}) soil than conventional soil (24.8 mg CO_2 50 g^{-1}) whereas no significant difference was noticed in 15-30 cm depth (Velmourougane, 2016).

Soil microbial respiration rates were found to be higher in soils from organic than sustainable and conventional farms, indicating highest activity of microorganisms in soils from organic farms (Liu *et al.*, 2007).

A significantly higher basal respiration was noticed in soil under organic management than soil with native vegetation and soil under conventional management (Araujo *et al.*, 2009).

2.1.3.7. Dehydrogenase activity

Marinari *et al.* (2006) observed there was significantly higher dehydrogenase activity in organic soils of Italy than their conventional counterparts.

Ramesh *et al.* (2010) concluded that in India, organic soils are having higher dehydrogenase activity than conventional soils and in Kerala the mean value was found to be 53.9 µg TPF g^{-1} soil 24 hr^{-1} for organic and 29.8 µg TPF g^{-1} soil 24 hr^{-1} for conventional soils.

Even though there was no significant difference in dehydrogenase activity between organic and conventional farms, it was higher in organic plots in both crops tested (Suja, 2013).

Velmourougane (2016) reported no significant difference was noticed in dehydrogenase activity in 0-15 cm as well as in 15-30 cm depth.

Sihi *et al.* (2017) also found that long term addition of organic residues has resulted in a significantly higher dehydrogenase activity in organic soils.

Similarly a significantly higher dehydrogenase activity was noticed in organic farms and its value ranged from 18.5 to 46.0 μg TPF g^{-1} soil 24 hr^{-1} in 25 different locations of conventional soils of Haryana while it ranged from 23.8 to 78.6 μg TPF g^{-1} soil 24 hr^{-1} under organic farming (Sheoran *et al.*, 2018).

2.1.3.8. Soil quality

Larson and Pierce (1991) defined soil quality as the capacity of soil to function within the ecosystem boundaries and interact positively with the environment, external to the ecosystem.

Maintaining soil quality is a human health concern also. Since air, water consumed by humans could be adversely affected by mismanagement and contamination of soils due to heavy metals, excess plant nutrients toxic elements, volatile and non- volatile organics and radioactive isotopes (Sheppard *et al.*, 1992).

Soil quality attributes are measurable soil properties that influence the capacity of soil to perform or function and serve as indicators of change in soil quality. The indicators that directly monitor the soil are grouped into physical, chemical and biological indicators (Singh and Ghosh, 2009).

Kumar (2009) reported that organic inputs take time to be apparently responsive in terms of productivity and soil health whereas conjunctive use of organic manures and mineral fertilizers proved conducive for stabilizing and sustaining soil quality and productivity in long run.

A soil property based rating index showed that a three-year organically managed field was found the most sustainable and conventionally managed field, the least sustainable system (Ikemura and Shukla, 2009).

Lei *et al.* (2017) on calculating the SQI of soils of organic and conventional farms of China reported that soil quality index was found in the range of 0.39-0.72 in the soils under organic management and in the range of 0.18-0.54 in the soils under conventional management. Except in one sampling location, the soils under organic farming were all higher than those under conventional farming.

Supriyadi *et al.* (2018) on comparing soil quality of organic and non-organic paddy fields in Indonesia reported that soil quality index of organic and non-organic paddy fields was 4.2 and 3.9 respectively. Even though a higher SQI was obtained in soils of organic farms, both soils were under low category. It has been concluded that 8 years of conversion has not been able to improve the overall soil properties.

2.2. HEAVY METAL CONTENT UNDER ORGANIC AND CONVENTIONAL MANAGEMENT

2.2.1. In plant

Verloo and Eeckhout, (1990) reported that growth period and rate of growth of plant as well as the chemical properties of soil affect the uptake of soil borne heavy metals.

Jinadasa *et al.* (1997) analysed Cd and Zn levels in vegetables and soil of Sydney and Australia and concluded that the increase in Cd and Zn in vegetables were due to repeated application of poultry manure.

Even though Cu, Zn, Ni, Pb and Cd analysed were not present at phytotoxic levels in amaranthus and cowpea, the content of Cd, Pb and Zn were found much above the food safety standards in GDR (Mathew, 1999).

Awashthi and Bhatnagar (2000) proposed the safe limit of Cd, Cu, Pb, Zn and Ni in plant samples (Indian standard) as 1.5, 30, 2.5, 50 and 1.5 $\mu g\ g^{-1}$ respectively and WHO (2007) proposed safe limit of Cd, Cu, Pb and Zn as 0.2, 40, 5 and 60 $\mu g\ g^{-1}$ respectively.

In organic carrots and buckwheat as well as in conventional wheat, Pb exceeded maximum levels and Cd exceeded maximum value in organic as well as conventional buckwheat (Malmauret *et al.*, 2002).

Chunilall *et al.* (2005) on analysing the heavy metal uptake of two edible amaranthus species grown in soils contaminated with Pb, Hg, Cd and Ni reported that green and red amaranthus species actively removed Cd from soil and translocated it from roots to shoots in a similar manner to that of the mechanism suggested for heavy metal accumulator species and both these exhibited an affinity for Ni and Cd with moderate to high levels in the leaves.

Rossi *et al.* (2008) on analysis of tomatoes grown under organic, conventional and integrated pest management systems reported that tomatoes grown organically were found to have significantly higher amount of lead than IPM and conventional system. Cu was found significantly higher in tomatoes from IPM system and Cd highest in organic tomato but no significant difference was noticed in Cd in berries grown under organic and IPM management.

Based on the study by Pandey and Pandey (2009), heavy metal concentration varied with species and plant parts considered for analysis and this was attributed to variable capabilities of plants to absorb or accumulate heavy metal. It was also reported that the metal concentration was found to be maximum in leaves (spinach and amaranthus) followed by fruits (tomato and egg plant) and minimum in roots (carrot, radish). In addition the concentration of Zn was reported to be highest followed by Pb, Cu, Ni and Cd except in tomato and egg plant in which Ni concentration level exceeded Cu.

Dotse (2010) reported that for Pb, all vegetables exceeded the safe limit except organic cucumber and conventional cabbage. For Cd, organic lettuce, green pepper, conventional green pepper and spinach all exceeded the FAO/WHO recommended limits.

Even though a significantly higher heavy metal was supplied to soil through organic fertilizer, semolina samples grown in conventional farm were found to be richer in Cd (82 mg kg^{-1} against 18 mg kg^{-1}), Cr (182 mg kg^{-1} against 50 mg kg^{-1}), and Cu (6.6 mg kg^{-1} against 5.8 mg kg^{-1}) and it was claimed that the organic system have the potential to reduce the amount of these elements in the soil solution, to reduce their availability and uptake by plants, and to influence their translocation processes to grains. But the samples grown in organic farms had higher concentrations of Ni (295 mg kg^{-1} against 166 mg kg^{-1}), Pb (94 mg kg^{-1} against 82 mg kg^{-1}), and Zn (13.6 mg kg^{-1} against 10.8 mg kg^{-1}) than those obtained from conventional fields (Zaccone *et al.*, 2010).

In a long term field trial conducted in U.K., Cooper *et al.* (2011) observed that Al, Cd, Cu, Ni, and Zn were significantly affected by crop management practices. Cd and Cu levels of wheat were higher in conventionally managed fields.

Lettuce, pepper and tomato that were grown organically and conventionally were analysed for heavy metals like Ni, Cd and Pb in Brazil by de Souza Araujo *et al.* (2014). Ni was found to be significantly higher in organic lettuce than in conventional lettuce and conventional pepper than in organic pepper. Cd and Pb content in lettuce, pepper and tomato grown in organic and conventional systems did not showed any significant difference. Ni content in organic and conventional tomato did not show any significant difference.

Pb content in most spices which were collected from the local markets Odisha and West Bengal were found to be within reference limits with the exception of cardamom, cinnamon, cloves, coriander, fenugreek, and ginger (Goswami and Mazumdar, 2014).

The organically and conventionally produced mango, acerola, strawberry persimmon and strawberry fruits in Brazil analysed were found to have low concentrations of Al, Ni, Cd and Cr that presented no risk to consumer health (Cardoso *et al.*, 2015).

Even though 64 per cent of conventionally grown vegetables showed a higher level of heavy metals, it's not possible to conclude that organically grown vegetables are safer than conventionally grown vegetables (Głodowska and Krawczyk, 2017).

2.2.2. In inputs

Content of heavy metals like Cd, Pb and Ni in vermicompost, sewage sludge, and FYM from cattle fed with sewage grown fodder were reported to be in the range of 2.2-7.2, 3.1-54.4 and 5.5-17.4 mg kg^{-1} respectively and content of Zn, Cu, Cd, Ni and Pb in rajphos were in the range of 1.4-2 per cent, 4.8-10.1, 6.2-19.6, 32.4-80.7 and 191-312 mg kg^{-1} respectively and in factamphos in the range of 0.11-0.36 per cent, 6.4-15.6, 9.2-25.1, 9.7-14.5, 48.1-95.4 mg kg^{-1} respectively (Mathew, 1999).

Condron *et al.* (2000) claimed that in New Zealand, most of the Cd that entered the farming system was introduced as a component of the fertiliser, superphosphate.

Apart from geological characteristics of soil, addition of liquid and soil manure or their derivatives add heavy metal content to soil (Martin *et al.,* 2006).

Lipoth and Schoenau, (2007) reported that the application of organic waste like sludge, compost or manure to agricultural land, add metals like Cd or Pb which are toxic apart from adding significant amount of nutrients.

During experimental years, the concentration of available Cd increased on application of poultry manure and the Cd uptake showed a proportional increase with available Cd content in soil almost in all treatments (Hanc *et al.*, 2008).

Park *et al.* (2010) reported that the increased concentration levels of metals in soil were due to repeated application of manure. For example, the annual metal inputs to agricultural lands in England and Wales from animal manures accounted to 524 mg (Zn), 1821 mg (Cu) and 225 mg (Ni) which accounts to 25.40 per cent of total input.Heavy metal concentration in certain organic manures recorded in a study conducted in Australia by them were as follows : Cow dung – 200 mg kg^{-1} Cu, 700 mg kg^{-1} Mn, 800 mg kg^{-1} Zn; Cow manure – 6.8 mg kg^{-1} As, 0.7 mg kg^{-1} Cd, 2.23 mg kg^{-1} Co, 17.5 mg kg^{-1} Cu, 172 mg kg^{-1} Mn, 9.6 mg kg^{-1} Ni, 7.5 mg kg^{-1} Pb, Poultry dropping – 450 mg kg^{-1} Cu, 1800 mg kg^{-1} Mn, 2300 mg kg^{-1} Zn.

Xiong *et al.* (2010) studied concentration of Cu in pig, cattle, chicken and sheep manure in China and suggested it can be major input of Cu to agriculture land.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled "Assessment of soil health and status of heavy metals in the certified organic farms of Kerala." was carried out in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani during August 2018- June 2019. The study was envisaged to assess and compare the soil health parameters and heavy metal status of the inputs and produce of certified organic farms and conventional farms of Kerala.

The materials used and methods followed for conducting the investigation are described in this chapter.

3.1. COMPARISON OF SOIL PROPERTIES OF CERTIFIED ORGANIC FARMS AND CONVENTIONAL FARMS OF KERALA

3.1.1. Collection of soil samples

Composite soil samples from 2 depths (0-15 cm and 15-30 cm) were collected from 10 locations each of certified organic farms and nearby conventional farms in different districts of Kerala. The samples were collected from 20 locations representing Northern, Hill, Central and Southern agro ecological zones of Kerala respectively. They include four samples each from certified organic and nearby conventional farmers' fields at Kannur (three from Kiliyanthara and one from Kootupuzha). Sampling was done during September 2018. The farms were under certification for 14 years. Two samples each from certified organic and nearby conventional farmers' fields of Wayanad (Pulpally area) were collected during February 2019. The farms were under certification for 15 years. From Palakkad, samples were collected from two certified organic and nearby conventional farmers' field of Kanjirapuzha during December 2018. The farms were under certification for 12 years. Two samples each from certified organic and nearby conventional farms in College of Agriculture, Vellayani Thiruvananthapuram were collected during March 2019. The farms were under certification for 10 years.

Plate 1: Sample collection locations of Northern Zone

Plate 2: Sample collection locations of Central Zone

Plate 3: Sample collection locations of Hill Zone

Plate 4: Sample collection locations of Southern Zone

Plate 5: *In situ* study conducted for enumeration of earthworms and arthropods

Table 1. Details of farmers selected for sample collection from organic and conventional farms

Sl.No.	Name and address of organic farmers	Name and address of conventional farmers
1	Joykutty Vincent Mannanal, Kiliyanthara P.O.	Thressiamma Alphonse Kalappurackal, Kiliyanthara P.O.
2	George Jose Nedumala, Kiliyanthara P.O.	Ajeesh Alphonse Kalappuracka,l Kiliyanthara P.O.
3	James C.J. Cherickathadathil, Kiliyanthara P.O.	Sebastian Kunnappally, Kiliyanthara P.O.
4	P.C. Joseph Panachakathil, Kootupuzha P.O.	Joji Jacob Nadackal, Kootupuzha P.O.
5	P.J. Chackochan Pullanthanickal, Mullankolli P.O.	K. P. Paulose Kambakathel, Mullankolli P.O.
6	Shaji P.A. Palapullickal, Kabanigiri P.O.	Philip Patassereyil, Kabanigiri P.O.
7	Dr. Mathew Mathew Kizakkekara (H) Kanjirapuzha P.O.	Sunny Joseph Kizakkekara (H) Kanjirapuzha P.O.
8	Thomas Mathew Kizhakekkara(H),Pallipadi Kanjirappuzha P.O. Palakkad	Jacob Thomas Kizhakekkara(H), Pallipadi Kanjirappuzha P.O. Palakkad
9	Model Organic farm, College of Agriculture, Vellayani	Instructional farm, 5th block, College of Agriculture, Vellayani
10	Organic farm (1st block), College of Agriculture, Vellayani	Instructional farm, 1st block, College of Agriculture, Vellayani

Soil samples which represent average fertility of each farm were collected, packed and labelled. The soil samples collected from each farmer's field were transported to COA, Vellayani. Fresh samples were used for enzyme analysis and enumeration of bacteria, fungi and actinomycetes. All the samples were air dried, powdered with wooden mallet, passed through 2 mm plastic sieve and stored in air tight containers for further analysis of physical and chemical parameters of soil.

3.1.2. *In situ* study

Pits of one metre cube soil was excavated and examined for enumeration of earth worms and arthropods in all the 10 organic and conventional farms and the method followed was direct counting method (Thakur, 2014).

3.1.3. Physical, chemical and biological parameters

Table 2. Analytical methods followed in soil analysis

Sl. No.	Parameter	Method	Reference
1	Bulk density	Undisturbed core sample	Black *et al.* (1965)
2	Water holding capacity	Core method	Gupta and Dakshinamurthy (1980)
3	pH	pH meter (1:2.5 soil water ratio)	Jackson (1973)
4	EC	Conductivity meter (1:2.5 soil water ratio)	Jackson (1973)
5	Organic matter	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 estimation using spectrophotometer	Bray and Kurtz (1945)

8	Available K	Neutral normal ammonium acetate extraction and estimation using flame photometry	Jackson (1973)
9	Exchangeable Ca and Mg	Versanate titration method	Hesse (1971)
10	Available S	$CaCl_2$ extraction and estimation using spectrophotometer.	Massoumi and Cornfield (1963)
11	Available Fe, Mn, Cu and Zn	0.1.N HCl extraction and estimation using atomic absorption spectrophotometer	Sims and Johnson (1991)
12	Available Boron	Hot water extraction and spectrophotometry (Azomethane-H method)	Gupta (1967)
13	Total Cd, Pb, Ni	Nitric-Perchloric (9:4) acid digestion and emission spectroscopy (ICP-OES)	Wei and Yang (2010)
14	Available Cd, Pb, Ni	0.1.N HCl extraction and estimation using atomic absorption spectrophotometer	Jackson (1973)
15	Soil respiration	Alkali trap and titrimety	Anderson (1982)
16	Dehydrogenase enzyme	Spectrophotometric method	Casida *et al.* (1964)
17	Bacteria	Nutrient Agar medium	Atlas and Parks (1993)
18	Fungi	Martin's Rose Bengal Agar	Martin (1950)
19	Actinomycetes	Ken knight's agar medium	Coppuccino and Sheman (1996)

3.1.4. Soil quality index calculation

Soil quality index was calculated using the simple additive SQI method followed by Amacher *et al.* (2007). In this method, soil parameters were given threshold values primarily based on the literature review.

Mineral soil property threshold levels, interpretations and associated soil index values are listed in table 3. The soil quality index values and associated soil property threshold values and interpretations were taken from Amacher *et al.* (2007). The individual index values for all soil properties measured are summed to give a total SQI for a particular soil:

Total SQI = ∑ individual soil property index values

The total SQI is then expressed as a percentage of the maximum possible value of the total SQI for the soil properties that are measured:

SQI (%) = (Total SQI / maximum possible total SQI for properties measured) x 100

Table 3. Soil quality index values and associated soil property threshold values and interpretations (Amacher *et al.*,2007)

Parameter	Level	Interpretation	Index
Bulk density ($Mg\ m^{-3}$)	>1.5	Possible adverse effects	0
	<=1.5	Adverse effects unlikely	1
SOC (%)	>5	High - excellent build up of organic C with all associated benefits	2
	1 to 5	Moderate – adequate levels	1
	<1	Low – could indicate possible loss of organic C from erosion or other processes	0

Available P (mg kg^{-1})	> 30	High – excellent reserve of available P for plants in acid soils, possible adverse effects to water quality from erosion of high P soils	1
	15 to 30	Moderate – adequate levels for plant growth	1
	< 15	Low – P deficiencies likely	0
Soil pH	<3.0	Severely acid-almost no plants can grow in this environment	-1
	3.01 to 4.0	Strongly acid - only the most acid tolerant plants can grow in this pH range and then only if organic matter levels are high enough to mitigate high levels of extractable Al and other metals.	0
	4.01 to 5.5	Moderately acid – growth of acid intolerant plants is affected depending on levels of extractable Al and other metals.	1
	5.51 to 6.8	Slightly acid – optimum for many plant species, particularly more acid tolerant species	2
	6.81 to 7.2	Near neutral – optimum for many plant species expect those that prefer acid soils	2
	7.21 to 7.5	Slightly alkaline – optimum for many plant species except those that prefer acid soils, possible deficiencies of available P and some metals (for example, Zn)	1
	7.51 to 8.5	Moderately alkaline – preferred by plants adapted to this pH range, possible P and metal deficiencies	1
	>8.5	Strongly alkaline – preferred by plants adapted to this pH range, possible B and other oxyanion toxicities	0

Available K ($mg\ kg^{-1}$)	> 500	High – excellent reserve	2
	100 to 500	Moderate – adequate levels for most plants	1
	< 100	Low – possible deficiencies	0
Ca ($mg\ kg^{-1}$)	>1000	High – excellent reserve, probably calcareous soil	2
	101 to 1000	Moderate – adequate levels for most plants	1
	10 to 100	Low – possible deficiencies	0
	<10	Very low – severe Ca depletion, adverse effects more likely	-1
Mg ($mg\ kg^{-1}$)	>500	High – excellent reserve	1
	50 to 500	Moderate – adequate levels for most plants	1
	<50	Low – possible deficiencies	0
S ($mg\ kg^{-1}$)	>100	High – may indicate gypsum soils, atmospheric deposition, mining areas, or industrial sources	0
	1 to 100	Moderate – adverse effects unlikely	1
	<1	Low – possible deficiencies in some soils	0
B ($mg\ kg^{-1}$)	> 0.5	Adequate	1
	< 0.5	Deficient	0
Fe ($mg\ kg^{-1}$)	> 10	High – effects unknown	0
	0.1 to 10	Moderate – effects unknown	1
	< 0.1	Low – possible deficiencies, possibly calcareous soil	0
Mn ($mg\ kg^{-1}$)	> 100	High – possible adverse effects to Mn sensitive plants	0
	11 to 100	Moderate – adverse effects or deficiencies less likely	1
	1 to 10	Low - adverse effects unlikely, possible deficiencies	1
	<1	Very low – deficiencies more likely	0

Cu (mg kg^{-1})	>1 0.1 to 1 < 0.1	High – possible toxicity to Cu sensitive plants, may indicate mining areas or industrial sources of Cu Moderate – effects unknown, but adverse effects unlikely Low – possible deficiencies in organic, calcareous, or sandy soils	0 1 0
Zn (mg kg^{-1})	> 10 1 to 10 <1	High – possible toxicity to Zn sensitive plants Moderate – effects unknown, but adverse effects unlikely Low – possible deficiencies in calcareous or sandy soils	0 1 0

3.2. COMPARISON OF HEAVY METAL CONTENT OF INPUTS USED IN ORGANIC AND CONVENTIONAL MANAGEMENT SYSTEMS

3.2.1. Collection of inputs

Samples of organic manures and fertilizers used as inputs of certified organic farms and conventional farms were collected during September 2018- March 2019. Organic (manure) samples include FYM, vermicompost, tejaswini and inorganic (fertilizer) samples include urea, Rajphos and factamfos from Thiruvananthapuram, Kannur and Palakkad from the farm stock.

3.3. COMPARISON OF HEAVY METAL CONTENT IN EDIBLE PLANT PARTS OF ORGANIC AND CONVENTIONAL MANAGEMENT SYSTEMS

3.3.1. Plant sample collection

Produce of both organic and conventional farms which includes greens, vegetables, fruits and spices at harvesting stage were collected from the locations mentioned below. Edible part of the following crops were collected.

Salad cucumber, capsicum, pepper and ginger were collected from Kannur. Yard long bean, banana, papaya and amaranthus from Thiruvananthapuram and bitter gourd and curry leaf from Wayanad.

The produce were first washed in running water and then in distilled water, pressed between folds of blotting paper, dried in shade and then dried in hot air oven at 65° C. The dried samples were finely ground and stored in air tight containers.

3.3.2. Inventory on yield and management practices

A survey on management practices and yield was conducted during plant sample collection. A pre structured questionnaire to collect the farming details was prepared for the purpose. Collected details were summarized below.

Table 4. Yield of crops in organic and conventional farms

Crop	Organic	Conventional
Salad cucumber	6.0 t ha^{-1}	7.0 t ha^{-1}
Capsicum	7.5 t ha^{-1}	9.0 t ha^{-1}
Bitter gourd	12.5 t ha^{-1}	15.0 t ha^{-1}
Yard long bean	12.0 t ha^{-1}	15.0 t ha^{-1}
Banana	22.5 t ha^{-1}	27.5 t ha^{-1}
Papaya	112.5 t ha^{-1}	125.0 t ha^{-1}
Pepper	1.45 t ha^{-1}	1.40 t ha^{-1}
Ginger	15.5 t ha^{-1}	17.0 t ha^{-1}
Amaranthus	11.0 t ha^{-1}	13.0 t ha^{-1}
Curry leaf	25.15 t ha^{-1}	26.30 t ha^{-1}

3.3.2.1. Details of general management practices adopted by farmers of organic and conventional farming in each zone

Northern zone

Four each of organic and nearby conventional farms of Kannur, three from Kiliyanthara and one from Kootupuzha area were surveyed during soil collection. All four organic farms were certified by INDOCERT, Aluva (NPOP certification) and a group certification (*ie.*, not individual certification) was followed. Certification was done from 2002 onwards. The area was generally hilly and sloppy. Major crops cultivated include coconut, cashew cocoa, banana, rubber, pepper, some fruit trees and vegetables. Mainly intercropping was practiced. Planting material was usually taken from previous crops. Major inputs used in farms include FYM, fermented FYM + oil cake, neem cake, bonemeal, sterameal, a byproduct from Tejaswini coconut farmer producer company + sterameal, dolomite, poultry manure, fish amino acid, neem cake +bone meal+ groundnut cake. In general, in all farms 2-3 cattles were maintained. Kasargode dwarf, Vechoor, Jersy, HF were the breeds commonly reared. Green leaf manure crops like glrycidia, cassia were seen in large numbers and are incorporated by farmers and also leaves of crops like *Macaranga indica* and crop residues are effectively utilized in farms. Many perennial trees like neem, East Indian rosewood, teak, tamarind and many other fruit trees were observed in the field. Plant protection methods adopted include the use of materials like neem oil, neem oil- garlic mixtue, cow urine etc.

Hill zone

Two each of certified organic and nearby conventional fields of farmers of Pulpally area were surveyed during soil collection. The farms were certified by INDOCERT, Aluva (NPOP certification) and the certification was done from 2004 onwards. Major crops cultivated include coconut, cocoa, coffee, banana, turmeric, pepper, many fruit trees, medicinal plants and vegetables. Major inputs used in the farms include FYM, arecanut waste, VAM, digested coffee husk + calcium carbonate and Varanasi compost.

Central zone

Two certified organic and nearby conventional fields of farmers of Kanjirapuzha area were surveyed during soil collection. The farms were certified by INDOCERT, Aluva (NPOP certification) and the certification was done from 2005 onwards. Major crops cultivated include coconut, arecanut, cocoa, banana, rubber, pepper, some fruit trees and vegetables. Spices like ginger and turmeric were grown by one farmer. Mainly intercropping was practiced. Major inputs used in the farms include FYM, neem cake, jeevamritham, compost made from goat manure+ FYM+ poultry manure and also another compost prepared using ayurvedic waste+ coirpith+ FYM+ poultry manure. Biocontrol agents like *Trichoderma, Pseudomonas* and biofertilizer like VAM were also used. Five - six cattles were maintained in farms. Drip irrigation was practiced for irrigating crops. Mulching was done using *Gliricidia*, *Macaranga indica* and tree loppings. Plant protection methods adopted include the use of COC, neem extract etc. For soil and water conservation by mulching and rainwater harvesting pits were taken in the field at different locations.

Southern zone

Two each of certified organic and conventionally managed fields in College of Agriculture, Vellayani were surveyed and sampled representing the Southern zone. The farms were certified by INDOCERT, Aluva (NPOP certification) and the certification was done from 2009 onwards. Major crops cultivated include banana, tubercrops and vegetables. Major inputs used in the farms include lime, FYM, poultry manure, coirpith compost, neemcake, rock phosphate, bone meal, groundnut cake and azolla. Animal manure was obtained from one Vechoor cow and remaining was purchased. Many fruit crops like sapota, mango, jack, gooseberry etc. were grown in farm. Green manure crops like *Gliricidia*, sunhemp, daincha were also grown in the field. Neem-oil garlic emulsion, neem extract etc. were used for plant protection.

3.3.3. Chemical analysis

3.3.3.1 Fertilizers

One gram of the well ground fertilizer sample was dissolved in 10 ml of concentrated HCl in a 100 ml beaker and evaporated almost to dryness. The residue was redissolved in 2 N HCl by gentle boiling. The solution was filtered through Whatman No.1 filter paper into a 100 ml volumetric flask, diluted to volume with double distilled water. This solution was used for the determination of Cu, Pb, Ni and Cd using the standard conditions for each element in an atomic absorption spectrophotometer (Everson, 1975).

3.3.3.2. Manures

One gram of the well ground sample was digested with 10 ml of concentrated HNO_3 and 3 ml $HClO_4$ in a 100 ml conical flask and evaporated to dryness. The residue was dissolved in 5 ml of 6 N HCl and made upto 50 ml with double distilled water and used for determination of total Cu, Pb, Ni and Cd using the standard conditions for each element in an atomic absorption spectrophotometer (AOAC, 1980).

3.3.3.3. Plant samples

The content of Cd, Ni, Pb, Cu and Zn were estimated in the extracts of plant samples prepared as under 3.3.3.2 above by direct reading using atomic absorption spectrophotometer.

3.4. STATISTICAL ANALYSIS

Data generated were analyzed statistically by paired t-test. Correlation study between soil health parameters and heavy metal content in plant part was also conducted. Yield and management practices were also correlated with heavy metal content in plant part.

Results

4. RESULTS

Soil samples were collected from organic and conventional farms in different parts of Kerala and analyzed in the laboratory for various physical, chemical and biological parameters. Samples of inputs being in use in organic and conventional farms as well as samples of plant produce collected were analyzed for heavy metal content. The results were expressed based on the statistically analyzed data pertaining to the experiment conducted during the course of investigation and are presented in this chapter.

4.1. COMPARATIVE EVALUATION OF THE EFFECT OF ORGANIC AND CONVENTIONAL FARMING ON SOIL PROPERTIES

4.1.1. Effect of organic and conventional farming on soil organic matter (%)

Organic matter status of organic and conventional farms presented in Table 5 indicated no significant difference between soils from organic and conventional farms at both depths. But a higher mean value was observed in soils of organic farms (3.49 per cent) than in soils of conventional farms (2.82 per cent) at 0-15 cm and similar was the case at 15-30 cm depth. At 15-30 cm depth, organic matter content ranged from 1.08-5.48 per cent and 1.28-4.40 per cent in soils of organic and conventional farms respectively. Highest organic matter content in soil of organic farms was observed in soil of Hill Zone (6.32 per cent) and lowest in soil of Southern Zone (1.58 per cent).

4.1.2. Effect of organic and conventional farming on physical properties

The physical properties studied were bulk density and water holding capacity. The data are presented in Table 6.

Effect of organic and conventional farming on bulk density and water holding capacity was not significant. Even though no significant difference was noticed in bulk density, mean value of bulk density was found to be more in soils of conventional farms (1.37 Mg m^{-3}) than in soils of organic farms (1.29 Mg m^{-3}). In case of Water holding capacity, soils under organic management (34.5%) were found to have more WHC than soils under conventional management (32.04%). Lowest bulk density was recorded in soil of Palakkad which was under organic management (1.00 Mg m^{-3}) and water holding capacity was also found to be highest in the same soil. Lowering of bulk density and increasing water holding capacity observed in organic farms are indicative of desirable trends in soil health.

4.1.3. Effect of organic and conventional farming on chemical properties

4.1.3.1. pH

Perusal of the data given in Table 7 revealed that effect of type of farming on soil pH is significant in surface soil. pH was found to be significantly higher in soils of conventional farms than in soils of organic farms. At 0-15 cm depth, mean value of pH was 5.33 and 5.64 in organic and conventional system respectively. But significant difference was noticed at 15-30 cm, although pH was more in conventional soil.

4.1.3.2. Electrical conductivity

Electrical conductivity was found to be higher in organic than in conventional soil at 15-30 cm as well as 15-30 cm depth (Table 8). But no significant difference was noticed at both depths. Mean value of electrical conductivity was about 0.123 dS m^{-1} and 0.113 dS m^{-1} in soils of organic farms at 0-15 cm and 15-30 cm depth respectively whereas in case of soils of conventional farms at 0-15 cm and 15-30 cm depth conductivity was found to be 0.088 dS m^{-1} and 0.068 dS m^{-1} respectively. EC is within the safe limit in organic farming.

4.1.3.3. Available Nitrogen

A significantly higher content of available N was observed in soils under organic management (319.9 kg ha^{-1}) than in soils under conventional management (253.4 kg ha^{-1}) at 0-15 cm depth whereas no significant difference was noticed in its content at 15-30 cm depth. Available N ranged from 150.5-376.3 kg ha^{-1} and 175.6-326.1 kg ha^{-1} in soils of organic and conventional farms respectively at 15-30 cm depth. Available Nitrogen was recorded highest in organic top soil of

Wayanad (464.13 kg ha^{-1}) (Table 9). Medium status of available N was noted in 50 per cent of the samples of organic farms, while it was seen only in 20 per cent of the samples of conventional farms.

4.1.3.4. Available Phosphorus

It is indicated in Table 10 that in surface soil available P was in the range of 7.7- 58.2 kg ha^{-1} and 2.5 -52.4 kg ha^{-1} in soils under organic management and conventional management respectively. At 15-30 cm depth available P ranged from 1.9-48.1 kg ha^{-1} and 1.2-44.2 kg ha^{-1} in soils of organic farms and conventional farms respectively. But no significant difference was noticed at both depths. Available P was found to be highest in organic top soil of Palakkad and lowest was recorded in subsurface soil from conventional farm of Kannur. Mean value of available P at 0-15 cm depth was found to be 25.69 kg ha^{-1} (high status) and 19.28 kg ha^{-1} (medium status) in soils from organic and conventional farms respectively.

4.1.3.5. Available Potassium

It was observed that (Table 11) available K was significantly higher in organic field than conventional at 0-15 cm depth and no significant difference was noticed at 15-30 cm depth. Available K was found to be in the range of 180.6 to 593.6 kg ha^{-1} with a mean of 376.46 kg ha^{-1} in soils of organic farms and 123.2 to 369.6 kg ha^{-1} with a mean of 230.72 kg ha^{-1} in soils of conventional farms at 0-15 cm depth. Highest available K was recorded in soil of hill zone (593.6 kg ha^{-1}) which was under organic management and lowest in soils of southern zone.

4.1.3.6. Available Calcium

It was evident from the data (Table 12), at 0-15 cm depth a significantly higher status of available Ca was found in soils under organic management (376 mg kg^{-1}) than in soils under conventional management (268 mg kg^{-1}) and no significant difference was noticed at 15-30 cm depth, yet soils of organic farms were found to have higher available Ca than soils of conventional farms. At 15-30 cm depth, available Ca ranged from 50-840 mg kg^{-1} and 10-690 mg kg^{-1} in soils of organic and conventional farms respectively. Except for 4 soil samples from organic and 3 samples from conventional farms, all other soils were found to be deficient in available Ca content.

4.1.3.7. Available Magnesium

In the surface soil (0-15 cm), available Mg was in the range of 36 to 222 mg kg^{-1} with a mean of 128.4 mg kg^{-1} in soils of organic farms and 12-258 mg kg^{-1} with a mean of 93.6 mg kg^{-1} in soils from conventional farms (Table 13). At 15-30 cm depth, the value ranged from 42-282 mg kg^{-1} with a mean of 96 mg kg^{-1} in soils from organic farms and 6-234 mg kg^{-1} with a mean of 76.8 mg kg^{-1} in soils from conventional farms. But no significant difference was noticed in available Mg at both depths. Deficiency of available Mg was noted in 50 per cent of soil samples of organic farms and in 70 per cent of samples of conventional farms.

4.1.3.8. Available Sulphur

It was seen from Table 14 that no significant difference was in the available S content between organic and conventional farms at both depths. At 0-15 cm depth, a higher available S was noticed in soils of organic farms than soils of conventional farms with a mean of 13.4 mg kg^{-1} and 9.9 mg kg^{-1} respectively. At 15-30 cm, the content ranged from 2-56 mg kg^{-1} in soils from organic farms with a mean of 14.2 mg kg^{-1} and 0.5-25 mg kg^{-1} with a mean of 9.5 mg kg^{-1} in soils from conventional farms. 70 per cent of soils under organic management and 50 per cent of soils under conventional management was found in sufficient range.

4.1.3.9. Available Boron

Data given in Table 15 reveals that available B was not significantly varying and was found to be slightly more in surface soil of organic farm (0.37 mg kg^{-1}) than soils of conventional farm (0.35 mg kg^{-1}) and at 15-30 cm depth, available B ranged from 0.02-2.38 mg kg^{-1} with a mean of 0.43 mg $kg^{-1}$and 0.02-1.6 mg kg^{-1} with a mean of 0.38 mg kg^{-1} available B was found in soils of organic and conventional farms respectively.

4.1.3.10. Available micronutrients

Available Fe, Mn, Zn and Cu was found to be higher in soil under organic management than in soil under conventional management at both depths. But a significant difference was noticed only in case of available Zn and Cu content at 0-15 cm depth (Tables 16-19). All micronutrients were found to be in sufficient range in all soils analysed. Available Zn was found in the range of 1.6 to 4.7 mg kg^{-1} with a mean of 3.1 mg kg^{-1} in soils from organic farms and 1.4-3.9 mg kg^{-1} with a mean of 2.37 mg kg^{-1} in soils from conventional farms at 0-15 cm depth. As depth increased the content reduced, but it was found to be higher in soils of organic farms than in soils of conventional farms (Table 18). A mean value of 3.92 and 2.51 mg kg^{-1} Cu was recorded in soil of organic and conventional farms respectively at 0-15 cm depth and at 15-30 cm depth, available Cu was 3.48 and 2.26 mg kg^{-1} in soils of organic and conventional system respectively.

4.1.3.11. Total heavy metals

Among the heavy metals anlaysed (Ni, Cd and Pb), Cd and Pb were found in traces in all locations (Tables 20-22). Total Ni was found to be highest in Hill zone and lowest in southern zone. Even though no significant difference was obtained, soils under organic management was found to have higher total Ni than soils under conventional management. At 0-15 cm depth, an average value of 45.67 mg kg^{-1} was recorded in soils under organic management and 39.02 mg kg^{-1} in soils under conventional management. At 15-30 cm depth, total Ni was about 30 mg kg^{-1} and 24.31 mg kg^{-1} in soils from organic and conventional farms respectively.

4.1.3.12. Available heavy metals

Available status of Cd, Pb and Ni given in (Tables 23, 24 and 25) reveals that Cd and Pb were found in traces in all soils. Available Ni ranged from 0.07 to 4.6 mg kg^{-1} with a mean of 0.79 mg kg^{-1} and 0.07-3.96 mg kg^{-1} with a mean of 0.68 mg kg^{-1} in soils of organic and conventional farms respectively at 0-15 cm depth. Available Ni was highest in soils of Wayanad. In surface soil of organic and conventional farm of Wayanad 4.58 and 3.95 mg kg^{-1} available Ni were recorded respectively.

4.1.4. Effect of organic and conventional farming on biological properties

4.1.4.1. Dehydrogenase activity

A significantly higher dehydrogenase activity was noticed in soils of organic farms than in soils of conventional farms at 0-15 cm and 15-30 cm depth (Table 26). A mean value of 26.6 and 14.27 µg of TPF g^{-1} soil 24 h^{-1} was recorded for surface soils of organic and conventional farms respectively. At 15-30 cm depth, dehydrogenase activity in soils of organic and conventional farms ranged from 2.5 to 49.9 µg of TPF g^{-1} soil 24 h^{-1} with a mean of 20 µg of TPF g^{-1} soil 24 h^{-1} and 0.2 to 38.8 µg of TPF g^{-1} soil 24 h^{-1} with a mean value of 9.88 µg of TPF g^{-1} soil 24 h^{-1} respectively. Highest amount of dehydrogenase activity in surface soil was recorded in soil of organic farm at Wayanad (64.49 µg of TPF g^{-1} soil 24 h^{-1}) and lowest in soil of conventional farm at Kannur (2.11 µg of TPF g^{-1} soil 24 h^{-1}).

4.1.4.2. Soil respiration

From Table 27 it was evident that at 0-15 cm depth soils of organic farms were recorded to have significantly higher respiratory activity than soils of conventional farms. Mean value of respiratory activity in surface soils organic farms and conventional farms were 10.25 mg CO_2 100 g^{-1} soil 24 h^{-1} and 7.94 mg CO_2 100 g^{-1} soil 24 h^{-1}. But at 15-30 cm depth although the respiratory activity was found to be more in organic farms than conventional farms, no significant difference was noticed. In surface soil (0-15 cm depth) highest respiratory activity was recorded in soil of hill zone (16.1 mg CO_2 100 g^{-1} soil 24 h^{-1}) and lowest in soil of northern zone (2.4 mg CO_2 100 g^{-1} soil 24 h^{-1}).

4.1.4.3. Bacteria, Fungi and Actinomycetes

A significantly higher population of bacteria, fungi and actinomycetes were found in soils under organic management than in soils under conventional management at 0-15 cm and 15-30 cm depths. Highest bacterial and fungal counts were observed in soils of hill zone in both organic and conventional systems (Tables 28-30). Surface soil of organic and conventional fields recorded 8.18 and 7.89 log cfu ml^{-1} bacteria respectively. At 15-30 cm depth, 8.03 and 7.71 log cfu ml^{-1} mean bacterial population was recorded in soils of organic and conventional farms respectively. Mean fungal population of surface soils of organic and conventional farms was 5.74 and 5.6 log cfu ml^{-1} respectively. And highest population of fungal was observed in soil of organic farm from Wayanad (6.03 log cfu ml^{-1}). Mean actinomycetes population of surface soils of organic and conventional farms was 4.35 and 4.26 log cfu ml^{-1} and at 15-30 cm mean value recorded was 4.24 and 3.93 log cfu ml^{-1} in soils under organic and conventional management respectively.

4.1.4.4. Earthworm and arthropod count

Data given in Table 31 showed that a significantly higher number of earthworms were found in organic farms with a mean of 35 numbers m^{-3} in organic farm and 15 numbers m^{-3} in conventional farm. Soil arthropods were found to be significantly higher in organic farms than in conventional farms. Arthropod count ranged between 9 and 35 with a mean of 22.3 numbers m^{-3} in soils of organic farms. In conventional farms, arthropod count varied in the range of 8-26 numbers m^{-3} with a mean of 15.4 numbers m^{-3}.

4.1.5. Soil quality index

Maximum index obtained was 61.1 per cent and it was observed in soils of hill zone in both organic and conventional management. Other than that, maximum index was obtained in northern zone as well as in southern zone which are under organic management. The lowest index obtained was 44.4 per cent. At 15-30 cm depth in 2 locations a similar index was got to both management system. But in all other regions organic soil was found to have higher index value (Table 32).

Table 5. Comparative evaluation of the effect of organic and conventional farming on SOM, per cent

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	3.90	3.16	3.06	2.72
2	3.16	2.72	2.39	2.05
3	3.90	2.66	3.06	2.79
4	2.62	1.85	2.69	1.71
5	4.10	4.24	4.47	4.07
6	6.32	5.18	5.18	4.40
7	5.38	2.32	5.48	1.92
8	2.15	2.42	2.08	1.51
9	1.75	1.71	1.08	1.28
10	1.58	1.98	1.31	1.98
Range	1.58-6.32	1.71-5.18	1.08-5.48	1.28-4.40
Mean	3.49	2.82	3.08	2.44
t stat	2.04		1.78	
p value	0.07		0.11	

Table 6. Comparative evaluation of the effect of organic and conventional farming on physical properties

Sample	Bulk density (Mg m^{-3})		Water holding capacity (%)	
	Organic	Conventional	Organic	Conventional
1	1.22	1.39	34.96	27.95
2	1.38	1.36	32.56	36.69
3	1.30	1.30	38.01	37.96
4	1.28	1.34	37.96	34.74
5	1.23	1.45	28.53	38.34
6	1.49	1.32	30.17	30.52
7	1.34	1.38	33	33.83
8	1.00	1.45	57.07	30.58
9	1.36	1.38	24.41	24.02
10	1.32	1.36	29.11	25.77
Range	1.00-1.49	1.30-1.45	24.41-57.07	24.02-38.34
Mean	1.29	1.37	34.578	32.04
t stat	1.55		0.84	
p value	0.16		0.42	

Table 7. Comparative evaluation of the effect of organic and conventional farming on pH

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	4.722	5.36	6.22	4.76
2	5.64	5.32	4.76	5.61
3	5.27	5.8	5.12	5.91
4	4.87	5.54	4.91	5.63
5	6.22	5.99	6.08	6.01
6	6.22	5.98	6.33	6.49
7	4.65	5.08	4.59	5.12
8	4.12	4.52	4.18	4.79
9	5.75	6.22	6.2	5.8
10	5.82	6.62	6.7	6.6
Range	4.12-6.22	5.08-6.62	4.18-6.70	4.76-6.60
Mean	5.3282	5.643	5.509	5.672
t stat	2.39		0.72	
p value	0.04		0.49	

Table 8. Comparative evaluation of the effect of organic and conventional farming on EC, dS m^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	0.06	0.05	0.06	0.03
2	0.05	0.06	0.08	0.07
3	0.08	0.04	0.07	0.05
4	0.1	0.08	0.09	0.05
5	0.08	0.13	0.05	0.07
6	0.18	0.12	0.2	0.1
7	0.28	0.14	0.16	0.09
8	0.08	0.16	0.05	0.09
9	0.17	0.05	0.06	0.06
10	0.15	0.05	0.31	0.07
Mean	0.123	0.088	0.113	0.068
Range	0.05-0.28	0.04-0.16	0.05-0.31	0.03-0.1
t stat	1.54		1.78	
p value	0.16		0.11	

Table 9. Comparative evaluation of the effect of organic and conventional farming on available N, kg ha^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	275.97	225.79	250.88	188.16
2	275.97	150.53	225.79	175.62
3	288.51	213.25	150.53	275.97
4	250.88	250.88	288.51	188.16
5	464.13	338.69	376.32	326.14
6	376.32	351.23	326.14	326.14
7	514.30	288.51	376.32	275.97
8	238.34	288.51	225.79	238.34
9	288.51	225.79	175.62	213.25
10	225.79	200.70	213.25	175.62
Range	225.8-514.3	150.5-351.2	150.5-376.3	175.6-326.1
Mean	319.87	253.39	260.92	238.34
t stat	2.71		1.04	
p value	0.02		0.33	

Table 10. Comparative evaluation of the effect of organic and conventional farming on available P, kg ha^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	9.07	5.04	6.94	2.46
2	16.24	2.46	2.13	0.11
3	25.09	14.22	13.33	9.18
4	22.18	22.85	22.74	12.77
5	7.73	2.58	0.78	0.11
6	25.09	27.55	22.62	13.66
7	25.09	22.51	19.04	11.54
8	58.24	20.16	48.16	22.40
9	58.02	52.42	31.25	44.24
10	10.19	22.96	8.18	12.88
Range	7.7-58.2	2.5-52.4	1.9-48.1	1.23-44.2
Mean	25.69	19.28	17.52	12.94
t stat	1.52		1.43	
p value	0.16		0.19	

Table 11. Comparative evaluation of the effect of organic and conventional farming on available K, kg ha^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	268.8	235.2	235.2	246.4
2	313.6	246.4	257.6	212.8
3	369.6	123.2	358.4	179.2
4	560	347.2	380.8	257.6
5	392	369.6	224	235.2
6	593.6	246.4	448	212.8
7	392	123.2	481.6	224
8	347.2	212.8	145.6	156.8
9	180.6	224	78.4	212.8
10	347.2	179.2	89.6	190.4
Range	180.6-593.6	123.2-369.6	78.4-481.6	156.8-257.6
Mean	376.46	230.72	269.92	212.8
t stat	3.68		1.33	
p value	0.005		0.22	

Table 12. Comparative evaluation of the effect of organic and conventional farming on available Ca, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	260	20	100	10
2	170	70	50	20
3	200	40	180	20
4	260	50	360	30
5	750	700	840	690
6	950	730	610	670
7	360	120	290	130
8	380	600	400	460
9	210	120	170	80
10	220	230	130	200
Range	170-950	20-730	50-840	10-690
Mean	376	268	313	231
t stat	2.37		2.05	
p value	0.04		0.07	

Table 13. Comparative evaluation of the effect of organic and conventional farming on available Mg, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	84	66	48	42
2	132	60	54	48
3	180	126	96	78
4	216	72	150	60
5	174	144	120	114
6	222	258	282	234
7	36	12	60	6
8	72	96	60	78
9	66	42	42	54
10	102	60	48	54
Range	36-222	12-258	42-282	6-234
Mean	128.4	93.6	96	76.8
t stat	2.19		1.77	
p value	0.06		0.11	

Table 14. Comparative evaluation of the effect of organic and conventional farming on available S, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	37	7	12.5	15
2	5.5	7.5	3	17
3	14	2.5	15.5	9.5
4	1.5	2.5	6	12.5
5	4	2	2	4
6	3	4.5	2.5	4
7	10	45	30	25
8	8	20	7	6
9	7	5.5	7.5	0.5
10	44	2.5	56	1.5
Range	1.5-44	2-45	2-56	0.5-25
Mean	13.4	9.9	14.2	9.5
t stat	0.52		0.79	
p value	0.61		0.44	

Table 15. Comparative evaluation of the effect of organic and conventional farming on available B, mg kg^{-1}

Sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	0.24	0.10	0.08	0.04
2	0.03	0.09	0.08	0.05
3	0.30	0.20	0.58	0.03
4	1.14	0.06	0.25	0.08
5	0.02	0.42	0.02	0.10
6	0.32	0.08	0.02	0.27
7	0.18	0.16	0.10	0.09
8	0.02	0.06	0.04	0.02
9	0.54	1.28	0.78	1.48
10	0.93	1.08	2.38	1.60
Range	0.02-1.1	0.06-1.3	0.02-2.38	0.02-1.6
Mean	0.37	0.35	0.43	0.38
t stat	0.12		0.43	
p value	0.91		0.67	

Table 16. Comparative evaluation of the effect of organic and conventional farming on available Fe, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	13.34	9.8	17.02	10.11
2	12.08	15.77	12.57	18.58
3	20.99	13.53	12.72	19.41
4	26.1	23	34.49	12.77
5	17.34	15.36	14.49	12.48
6	26.43	30.22	25.08	17.93
7	15	12.05	12.65	15.56
8	38.61	31.4	28.21	21.9
9	11.25	10.63	12.91	14.3
10	36.32	34.09	29.42	31.43
Range	11.2-38.6	9.8-34.1	12.6-34.5	10.1-31.4
Mean	21.75	19.59	19.96	17.45
t stat	1.8		0.936	
p value	0.01		0.374	

Table 17. Comparative evaluation of the effect of organic and conventional farming on available Mn, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	24.02	11.96	18.42	16.79
2	40.98	23.94	17.7	18.36
3	30.95	22.86	25.49	25.53
4	84.62	37.02	89.83	12.91
5	93.69	110.4	75.18	86.23
6	121.3	67.29	116.1	58.65
7	20.35	3.14	18.55	4.25
8	30.04	43.59	33.82	30.86
9	11.41	9.66	10.04	8.54
10	13.27	11.09	10.98	12.49
Range	11.4-121.3	3.1-110.4	10.0-116.1	4.3-58.7
Mean	47.06	34.09	41.61	27.46
t stat	1.78		1.54	
p value	0.108		0.157	

Table 18. Comparative evaluation of the effect of organic and conventional farming on available Zn, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	4.18	2.11	1.71	1.39
2	2.61	1.47	1.11	1.18
3	2.18	2.08	2.06	1.72
4	2.96	1.74	3.27	1.04
5	4.67	3.92	4.15	3.63
6	3.61	3.02	3.34	2.47
7	3.03	1.41	2.5	0.99
8	1.62	1.43	1.52	2.74
9	4.17	3.47	2.85	3.6
10	2.16	3.1	1.76	2.6
Range	1.6-4.7	1.4-3.9	1.1-3.34	0.99-3.6
Mean	3.12	2.38	2.43	2.14
t stat	2.77		0.86	
p value	0.022		0.414	

Table 19. Comparative evaluation of the effect of organic and conventional farming on available Cu, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	3.82	2.18	2.62	1.86
2	3.66	4.28	3.54	3.39
3	4.41	2.48	4.31	1.19
4	8.94	3.26	8.57	2.32
5	6.52	3.4	5.92	3.9
6	1.48	1.23	1.59	1.14
7	1.89	1.5	1.48	1.1
8	3.56	3.24	3.54	4.87
9	1.29	1.42	0.93	1.09
10	3.69	2.17	2.33	1.75
Range	1.3-8.9	1.2-4.3	0.9-8.6	1.1-4.9
Mean	3.93	2.52	3.48	2.26
t stat	2.38		1.74	
p value	0.041		0.116	

Table 20. Comparative evaluation of the effect of organic and conventional farming on total Cd, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	0.384	0.357	0.321	0.318
2	0.487	0.472	0.374	0.356
3	0.432	0.422	0.379	0.282
4	0.468	0.472	0.367	0.365
5	0.494	0.463	0.385	0.369
6	0.388	0.353	0.333	0.325
7	0.335	0.323	0.282	0.276
8	0.294	0.282	0.244	0.135
9	0.232	0.235	0.159	0.167
10	0.212	0.236	0.143	0.155
Range	0.21-0.49	0.24-0.47	0.14-0.38	0.16-0.37
Mean	0.373	0.362	0.299	0.275
t stat	1.95		1.77	
p value	0.082		0.111	

Table 21. Comparative evaluation of the effect of organic and conventional farming on total Pb, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	0.213	0.207	0.183	0.172
2	0.233	0.223	0.194	0.199
3	0.221	0.218	0.188	0.181
4	0.211	0.215	0.174	0.172
5	0.244	0.234	0.187	0.171
6	0.216	0.208	0.177	0.159
7	0.211	0.198	0.154	0.143
8	0.212	0.213	0.141	0.152
9	0.215	0.219	0.168	0.155
10	0.206	0.209	0.153	0.167
Range	0.21-0.24	0.2-0.23	0.15-0.19	0.14-0.2
Mean	0.218	0.214	0.172	0.167
t stat	1.86		1.34	
p value	0.0958		0.213	

Table 22. Comparative evaluation of the effect of organic and conventional farming on total Ni, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	64.7	59.3	42.50	11.2
2	93.06	70.46	70.66	65.74
3	85.12	65.12	78.42	62.46
4	73.62	59.22	62.42	50.62
5	43.58	38.56	10.01	13.64
6	39.12	37.62	9.72	8.24
7	39.96	34.42	16.64	16.58
8	16.64	24.62	9.06	14.048
9	0.445	0.432	0.333	0.311
10	0.468	0.455	0.264	0.232
Range	0.44-93.06	0.43-70.5	0.26-78.4	0.23-65.7
Mean	45.67	39.02	30	24.31
t stat	2.19		1.62	
p value	0.056		0.14	

Table 23. Comparative evaluation of the effect of organic and conventional farming on available Cd, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	0.0815	0.0802	0.0712	0.0711
2	0.0938	0.0845	0.0636	0.0627
3	0.0913	0.0865	0.0747	0.0736
4	0.0915	0.0906	0.081	0.0798
5	0.0964	0.0856	0.0821	0.0712
6	0.0866	0.0848	0.0512	0.0514
7	0.0726	0.0712	0.0432	0.0495
8	0.0683	0.0632	0.0332	0.0341
9	0.0442	0.0456	0.0288	0.0279
10	0.0381	0.0424	0.0245	0.0231
Range	0.04-0.096	0.04-0.090	0.025-0.08	0.023-0.079
Mean	0.0764	0.0735	0.0554	0.05444
t stat	2.03		0.688	
p value	0.07		0.509	

Table 24. Comparative evaluation of the effect of organic and conventional farming on available Pb, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	0.0912	0.0895	0.0863	0.0845
2	0.0965	0.0948	0.0891	0.0839
3	0.0878	0.0882	0.0764	0.0725
4	0.0885	0.0791	0.0762	0.0754
5	0.0985	0.0851	0.0815	0.0802
6	0.0888	0.0865	0.0866	0.0828
7	0.0762	0.0729	0.0726	0.0712
8	0.0667	0.0733	0.0683	0.0632
9	0.0685	0.0694	0.0442	0.0456
10	0.0591	0.0619	0.0311	0.0364
Range	0.06-0.098	0.061-0.094	0.03-0.089	0.036-0.085
Mean	0.0822	0.0801	0.0712	0.0696
t stat	1.16		1.63	
p value	0.276		0.136	

Table 25. Comparative evaluation of the effect of organic and conventional farming on available Ni, mg kg^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	0.245	0.222	0.112	0.109
2	0.389	0.368	0.098	0.096
3	0.362	0.343	0.101	0.089
4	0.243	0.226	0.087	0.085
5	4.581	3.964	4.015	3.359
6	1.691	1.236	1.598	1.149
7	0.121	0.126	0.062	0.065
8	0.135	0.134	0.071	0.069
9	0.074	0.073	0.066	0.065
10	0.093	0.089	0.059	0.058
Range	0.074-4.6	0.07-3.96	0.06-4.02	0.06-3.35
Mean	0.793	0.678	0.627	0.515
t stat	1.62		1.49	
p value	0.14		0.168	

Table 26. Comparative evaluation of the effect of organic and conventional farming on dehydrogenase activity, µg of TPF g^{-1} soil 24 h^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	14.40	4.03	10.94	4.13
2	16.70	6.33	36.66	2.30
3	39.54	2.11	3.65	0.96
4	29.94	3.02	19.00	1.73
5	64.49	49.14	36.09	37.43
6	59.12	37.24	49.90	38.77
7	14.78	4.99	31.86	4.22
8	8.45	30.52	5.57	7.10
9	3.65	2.21	3.84	1.92
10	14.97	3.07	2.50	0.19
Range	3.7-64.5	2.1-49.1	2.5-49.9	0.2-38.8
Mean	26.60	14.27	20.00	9.88
t stat	2.46		2.56	
p value	0.04		0.03	

Table 27. Comparative evaluation of the effect of organic and conventional farming on respiratory activity, mg CO_2 100 g^{-1} soil 24 h^{-1}

sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	9.82	2.36	9.43	3.54
2	11.39	8.64	7.86	5.50
3	12.18	5.89	3.14	7.07
4	5.11	3.14	5.50	2.36
5	12.57	14.93	7.07	6.68
6	16.11	13.75	9.82	7.46
7	7.86	3.14	1.96	8.25
8	13.75	12.96	9.82	10.61
9	2.36	3.54	1.18	3.93
10	11.39	11.00	3.93	3.54
Range	2.4-16.1	2.4-14.9	1.2-9.8	2.4-10.6
Mean	10.25	7.94	5.97	5.89
t stat	2.34		0.07	
p value	0.04		0.95	

Table 28. Comparative evaluation of the effect of organic and conventional farming on bacterial count, log cfu ml^{-1}

Sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	8.08	7.61	8.04	7.8
2	8.1	7.78	8.04	7.69
3	8.42	7.54	7.84	7.19
4	8.29	7.81	8.07	7.39
5	8.63	8.39	8.39	8.37
6	8.61	8.36	8.44	8.31
7	7.98	7.73	8.14	7.79
8	7.85	8.21	7.9	7.84
9	7.75	7.63	7.78	7.54
10	8.06	7.8	7.64	7.19
Range	8.1-8.6	7.6-8.4	7.6-8.4	7.1-8.4
Mean	8.18	7.89	8.03	7.71
t stat	2.94		4.38	
p value	0.016		0.0018	

Table 29. Comparative evaluation of the effect of organic and conventional farming on fungal count, log cfu ml^{-1}

Sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	5.61	5.49	5.49	5.37
2	5.69	5.57	5.66	5.58
3	5.79	5.55	5.59	5.51
4	5.83	5.65	5.62	5.59
5	5.91	5.87	5.81	5.72
6	6.03	5.86	5.83	5.87
7	5.72	5.64	5.59	5.48
8	5.69	5.75	5.62	5.52
9	5.5	5.25	5.45	5.21
10	5.59	5.37	5.5	5.11
Range	5.5-6	5.3-5.9	5.5-5.8	5.1-5.9
Mean	5.74	5.60	5.62	5.50
t stat	4.49		3.26	
p value	0.0015		0.0098	

Table 30. Comparative evaluation of the effect of organic and conventional farming on actinomycetes count, log cfu ml^{-1}

Sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	4.24	4.15	4.04	3.8
2	4.31	4.24	4.15	3.65
3	4.24	4.04	4.07	4.09
4	4.45	4.34	4.52	3.89
5	4.56	4.43	4.37	4.15
6	4.52	4.42	4.24	4.13
7	4.31	4.24	4.15	3.65
8	4.48	4.56	4.31	4.37
9	4.24	4.04	4.24	3.8
10	4.15	4.1	4.31	3.8
Range	4.2-4.6	4-4.6	4-4.5	3.8-4.3
Mean	4.35	4.26	4.24	3.93
t stat	3.67		4.05	
p value	0.0051		0.0029	

Table 31. Comparative evaluation of the effect of organic and conventional farming on earthworm and arthropod population, number m^{-3}

Sample	Earthworms		Soil arthropods	
	Organic	Conventional	Organic	Conventional
1	42	22	30	22
2	23	12	24	15
3	35	13	28	21
4	18	8	15	10
5	70	12	35	9
6	20	15	12	10
7	60	14	33	22
8	21	23	22	26
9	16	15	15	8
10	45	16	9	11
Range	18-70	8-23	9-35	8-26
Mean	35	15	22.3	15.4
t stat	3.22		2.64	
p value	0.01		0.026	

Table 32. Soil quality index of soils, per cent

Sample	0-15 cm		15-30 cm	
	Organic	Conventional	Organic	Conventional
1	50	44.4	47.1	29.4
2	61.1	44.4	41.2	35.3
3	55.6	50.0	52.9	35.3
4	61.1	50.0	52.9	35.3
5	61.1	61.1	52.9	52.9
6	61.1	61.1	52.9	47.1
7	44.4	44.4	41.2	35.3
8	55.6	44.4	47.1	29.4
9	55.6	55.6	41.2	35.3
10	61.1	55.6	47.1	47.1
Range	44.4-61.1	44.4-61.1	41.2-52.9	29.4-52.9
Mean	56.67	51.1	47.65	38.24

4.2. HEAVY METAL/ MICRONUTRIENT CONTENT IN INPUTS

From Tables 33 and 34, it was clear that, except for the content of Cu in fertilizers and manures, no other heavy metals were observed to be significantly different in manures and fertilizes. Among manures analysed, highest Zn content was found in FYM (114.8 mg kg^{-1}) and lowest in tejaswini (98 mg kg^{-1}) and Cu was found highest in vermicompost (136 mg kg^{-1}) and lowest in tejaswini (80 mg kg^{-1}). Highest content of Zn was found in rajphos and lowest in urea. Zn content in urea, rajphos and factamfos were 5.56, 2000 and 1200 mg kg^{-1} respectively. Cu content in urea, rajphos and factamfos were 1.45, 4.92 and 6.48 mg kg^{-1} respectively. Ni content in FYM, vermicompost and tejaswini were 1.1, 6.2 and 1.3 mg kg^{-1} respectively. Urea, rajphos and factamfos were 1.3, 10.3 and 3.2 mg kg^{-1} respectively.

Cd and Pb content in inputs were presented in Table 34. Cd content in FYM, vermicompost and tejaswini were 0.88, 1.4 and 0.82 mg kg^{-1} respectively. In fertilizers, urea, rajphos and factamfos Cd content recorded were 1.1, 2.1 and 3.2 mg kg^{-1} respectively. Content of Pb in FYM, vermicompost and tejaswini were 0.9, 2.5 and 1.1 mg kg^{-1} respectively whereas in urea, rajphos and factamfos, Pb content recorded were 1.9, 63.6 and 23.4 mg kg^{-1} respectively.

4.3. HEAVY METAL CONTENT IN PLANT PRODUCE

Zn and Cu content in 10 samples of plant produce were presented in Table 35. Safe limit standard set by WHO is 60 mg kg^{-1} for Zn in plants. Zn content in amaranthus, yard long bean, curry leaf and salad cucumber in organic farms and amaranthus in conventional farms exceeded this limit. In amaranthus, Zn content was found to be high which is 96 mg kg^{-1} in organic and 105.6 mg kg^{-1} in conventional amaranathus and content of Zn in yardlong bean, salad cucumber and curry leaf from organic farms were found to be just exceeding the safe limit. About 64, 62.8 and 60.4 mg/kg respectively. Zn in plants was found to be significantly affected by management practices also.

In case of Cu, content of Cu in all crop produce was found to be well within the safe limit which is 40 mg/kg. Cu was found to be highest in pepper from organic farm. In case of conventionally managed crops, Cu content was high in salad cucumber followed by pepper.

The content of Cd, Ni and Pb, the content was found to be very much within the food safety standards (Table 36). And no significant difference was noticed in the content of Cu, Ni, Pb and Cd between the crops grown in conventional and organic management.

4.4. CORRELATION STUDIES

Correlation between Zn and Cu in plant produce and physical and chemical properties which showed a significant difference in paired t test was represented in Table 37 in case of organic farms and Table 38 in case of conventional farms. Available Zn was found to be significantly correlated with the content of Zn in plant produce in both organic and conventional management.

From Tables 39 and 40, it can be observed that Zn and Cu content in plant produce was negatively correlated with yield in both organic and conventional systems. But no significant correlation was obtained between these.

No significant correlation was observed between heavy metal content plant parts and heavy metal content in inputs (Tables 41, 42). But a positive correlation was observed between the content in manure and fertilizers and that in plant produce.

Table 33. Heavy metal / micronutrient content (Zn, Cu and Ni) in inputs

Sample	Zn		Cu		Ni	
	mg kg^{-1}					
	Manure	Fertilizer	Manure	Fertilizer	Manure	Fertilizer
1	114.8	5.56	136	1.45	1.1	1.3
2	108	2000	156	4.92	6.2	10.3
3	98	1200	80	6.48	1.3	3.2
Mean	106.93	1068.52	124	4.28	2.86	4.93
t stat	1.65		5.07		1.83	
p value	0.24		0.037		0.208	

Table 34. Heavy metal content (Cd and Pb) in inputs

Sample	Cd		Pb	
	mg kg^{-1}			
	Manure	Fertilizer	Manure	Fertilizer
1	0.88	1.1	0.9	1.9
2	1.4	2.1	2.5	63.6
3	0.82	3.2	1.1	23.4
Mean	1.03	2.13	1.5	29.6
t stat	1.67		1.6	
p value	0.23		0.25	

Manures	Fertilizers
1. FYM	1. Urea
2. Vermicompost	2. Rajphos
3. Tejawsini	3. Factamfos

Table 35. Heavy metal / micronutrient content in plant produce (Zn and Cu)

Sample	Zn		Cu	
	(mg kg^{-1})			
	Organic	Conventional	Organic	Conventional
Salad cucumber	62.8	57.2	24	28.1
Capsicum	38.8	42.8	12.8	10.4
Bittergourd	58.8	52	20.8	11.6
Yard long bean	64	55.6	5.6	8.8
Banana	27.2	19.6	0.4	4.4
Papaya	34	27.6	4.8	6.8
Pepper	44.8	33.2	33.2	23.2
Ginger	40.4	35.6	8.8	12.4
Amaranthus	96	105.6	21.2	14
Curry leaf	60.4	44	16	13.2
Mean	52.72	47.32	14.76	13.29
Safe limit (WHO/FAO)	60		40	
t stat	2.31		0.821	
p value	0.045		0.432	

Table 36. Heavy metal content in plant produce (Cd, Ni and Pb)

Sample	Cd		Ni		Pb	
	(mg kg^{-1})					
	Organic	Conventional	Organic	Conventional	Organic	Conventional
Salad cucumber	0.09	0.079	0.282	0.232	0.214	0.198
Capsicum	0.192	0.163	0.321	0.314	0.212	0.194
Bittergourd	0.186	0.189	0.364	0.355	0.184	0.163
Yard long bean	0.059	0.059	0.458	0.412	0.176	0.148
Banana	0.108	0.112	0.343	0.351	0.245	0.233
Papaya	0.063	0.061	0.221	0.211	0.146	0.158
Pepper	0.172	0.169	0.386	0.391	0.124	0.176
Ginger	0.134	0.132	0.321	0.287	0.184	0.178
Amaranthus	0.194	0.191	0.412	0.466	0.097	0.09
Curry leaf	0.076	0.068	0.389	0.377	0.112	0.109
Mean	0.127	0.122	0.35	0.34	0.169	0.165
Safe limit(WHO/FAO)	1.5		1.5 (Indian standard)		2.5	
t stat	1.69		1.06		0.65	
p value	0.124		0.316		0.53	

Table 37. Correlation between heavy metal content of plant produce and soil properties of soils under organic management

	Zn plant	Cu plant	pH	Avail N	Avail K	Avail Ca	Avail Zn	Avail Cu
Zn plant	1							
Cu plant	0.448	1						
pH	0.138	-0.355	1					
Avail N	0.338	0.169	0.629	1				
Avail K	-0.335	0.373	-0.188	0.131	1			
Avail Ca	0.174	0.250	0.550	0.828	0.516	1		
Avail Zn	**0.649***	0.184	0.237	0.632	-0.453	0.307	1	
Avail Cu	-0.332	0.313	-0.552	-0.069	0.682	-0.019	-0.329	1

Table 38. Correlation between heavy metal content of plant produce and soil properties of soils under conventional management

	Zn plant	Cu plant	pH	Avail N	Avail K	Avail Ca	Avail Zn	Avail Cu
Zn plant	1							
Cu plant	0.258	1.000						
pH	0.593	0.349	1.000					
Avail N	0.370	-0.434	-0.216	1.000				
Avail K	0.565	0.313	0.085	0.318	1.000			
Avail Ca	0.508	-0.199	-0.086	0.710	0.364	1.000		
Avail Zn	**0.898***	0.370	0.798	0.246	0.351	0.377	1.000	
Avail Cu	0.091	0.132	-0.266	-0.087	0.542	0.334	-0.214	1

Table 39. Correlation between heavy metal content of organic plant produce and yield of crops

	Organic yield	Zn plant	Cu plant
Organic yield	1		
Zn plant	-0.351	1	
Cu plant	-0.472	0.448	1

Table 40. Correlation between heavy metal content of conventional plant produce and yield of crops

	Conventional yield	Zn plant	Cu plant
Conventional yield	1		
Zn plant	-0.332	1	
Cu plant	-0.456	0.258	1

Table 41. Correlation between heavy metal content of organic plant produce and nutrient management

	Cd plant	Ni plant	Pb plant	Zn plant	Cu plant	Cd manure	Ni manure	Pb manure	Cu manure	Zn manure
Cd plant	1									
Ni plant	-0.674	1.000								
Pb plant	-0.435	0.958	1.000							
Zn plant	-0.871	0.950	0.821	1.000						
cu plant	0.823	-0.135	0.154	-0.438	1.000					
Cd manure	0.693	0.065	0.347	-0.250	0.980	1.000				
Ni manure	0.780	0.064	0.224	-0.373	0.997	0.992	1.000			
Pb manure	0.828	-0.144	0.145	-0.446	1.000	0.978	0.997	1.000		
Cu manure	0.070	0.690	0.868	0.429	0.624	0.767	0.678	0.617	1.000	
Zn manure	-0.565	0.990	0.989	0.897	0.003	0.202	0.075	-0.005	0.783	1

Table 42. Correlation between heavy metal content of conventional plant produce and nutrient management

	Cd plant	Ni plant	Pb plant	Zn plant	Cu plant	Cd ferti	Ni ferti	Pb ferti	Cu ferti	Zn ferti
Cd plant	1									
Ni plant	1.000	1.000								
Pb plant	0.987	0.985	1.000							
Zn plant	0.982	0.979	0.999	1.000						
Cu plant	0.789	0.798	0.682	0.657	1.000					
Cd ferti	0.969	0.965	0.996	0.998	0.613	1.000				
Ni ferti	0.412	0.425	0.263	0.230	0.884	0.173	1.000			
Pb ferti	0.542	0.555	0.403	0.372	0.944	0.317	0.989	1.000		
Cu ferti	1.000	1.000	0.989	0.983	0.785	0.971	0.405	0.536	1.000	
Zn ferti	0.794	0.785	0.880	0.896	0.254	0.920	-0.227	-0.080	0.799	1

Discussion

5. DISCUSSION

The important results of the investigation "Assessment of soil health and status of heavy metals in the certified organic farms of Kerala" presented in the preceding chapter are discussed in this chapter in the light of evidences from published literature, keeping in view the objective proposed in the study.

5.1. EFFECT OF ORGANIC AND CONVENTIONAL MANAGEMENT PRACTICES ON SOIL HEALTH

5.1.1. Effect on physical properties

Results on analysis of bulk density and water holding capacity (Table 6) revealed that, even though no significant difference was noticed in the physical properties, mean bulk density and water holding capacity were found to be decreasing and increasing respectively in soils under organic management than soil under conventional management. The mean values of bulk density in soils of organic farms and conventional farms were 1.29 and 1.37 Mg m^{-3}. These findings are in conformity with the findings of Hathaway-Jenkins *et al.* (2010) and Colla *et al.* (2000).

The difference in BD between organic and conventional systems were mainly because of the difference in the organic matter content of soil (Sihi *et al.*, 2017) and in general, for improved physical properties in organic soil, organic matter addition is stated as the major driving force (Colla *et al.*, 2000). However to create measurable changes in soil properties, particularly in case of physical properties, repeated addition of relatively large organic carbon inputs (up to 65 t organic carbon ha^{-1}) were needed (Bhogal *et al.*, 2009). This is in acceptance with the result obtained in the present study. From Table 5, it is clear that no significant difference was noticed in SOM content between organic and conventional systems. But increasing tend observed in soil organic matter content in soils of organic farms might have contributed to lowering of bulk density and improvement in water holding capacity of organic field. Though not significant, the increasing trend in water holding capacity and lowering of bulk density in soils of organic farms than in conventional farms indicate the relationship to soil health in terms of crop productivity potential, compaction, plow pan water movement, porosity and workability (Venugopal, 2007).

5.1.2. Effect on chemical properties

5.1.2.1. pH

Surface soils of organic farms and conventional farms recorded a mean pH of 5.33 and 5.64 respectively. A significantly higher pH was obtained in conventional farms (at 0-15 cm depth) than organic farms (Fig. 1, Table 7). At 15-30 cm depth also soils under organic management were found more acidic than soils under conventional management. All soils analysed were found to be moderately acidic to slightly acidic. Similar result was reported by Reganold *et al.* (1993). Reduction in pH in soils of organic farms might be due to production of weak organic acids on decomposition of organic residues added (Sihi *et al.*, 2017). Velmourougane (2016) also concluded that the drop in pH in organic farms might be due to the effect of organic manure on soil reaction.

5.1.2.2. Electrical conductivity

Electrical conductivity was found to be higher in soils of organic than in conventional farms at 0-15 cm as well as 15-30 cm depth. Surface soils of organic farms and conventional farms recorded a mean EC of 0.123 and 0.088 dS m^{-1} respectively. But no significant difference was noticed at both depths (Table 8). Ramesh *et al.* (2010) on analysis of different soils of organic and conventional samples across India reported that mean electrical conductivity of 30 soil samples from Kerala showed a higher value in soils from organic farms(1.74 dS m^{-1}) than from conventional (1.18 dS m^{-1}) farms. A similar result was obtained Ozlu and Kumar (2018) when low, medium and heavy manure application were compared with fertilizer application rates at different depths in South Dakota, USA.

The increase in soil electrical conductivity due to manure addition might be the consequence of amount of dissolved salts in the manures (Eghball, 2002). Feed

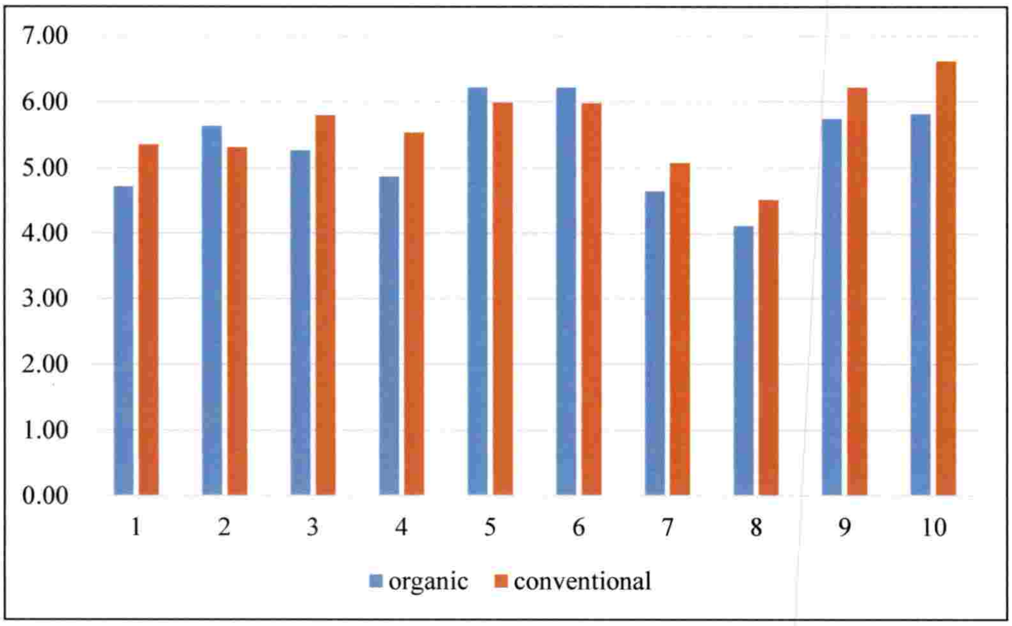

Fig. 1. Effect of organic and conventional management on pH at 0-15 cm depth

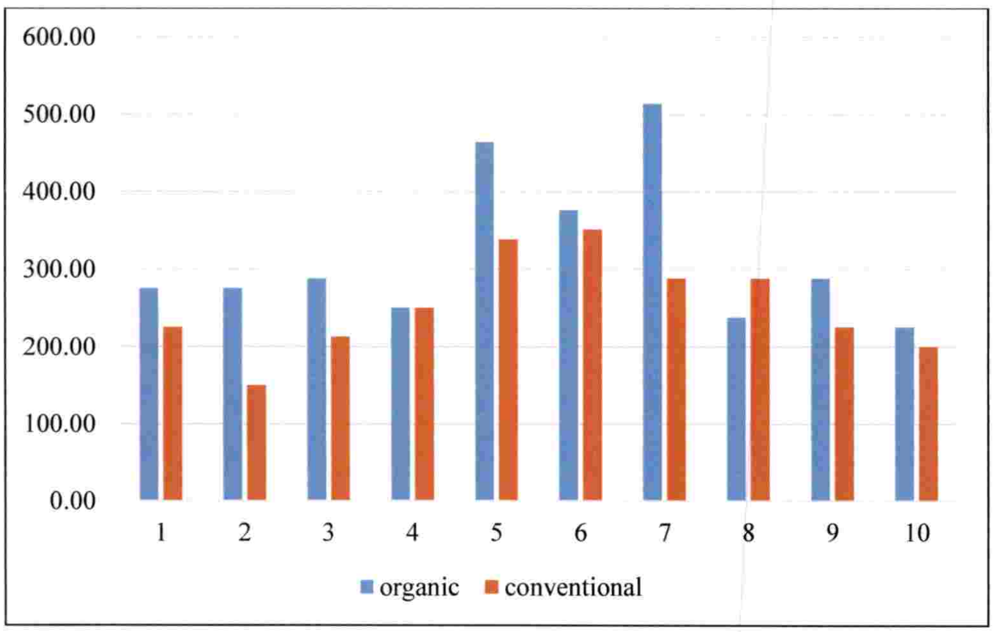

Fig. 2. Effect of organic and conventional management on available N (kg ha^{-1}) at 0-15 cm depth

additives might be the source of salts in the manures (Ozlu and Kumar, 2018). Green manure addition in organic farming might also have acted as a supplementary source of cations, possibly from lower soil depths that are discharged at the soil surface through leaching and decomposition activities (Suja, 2013).

5.1.2.3. Available Nitrogen

A significantly higher amount of available nitrogen was observed in organic farms than in conventional farms at 0-15 cm (Table 9, Fig.2). Mean value of available N recorded in surface soils of organic and conventional farms was 319.87 and 253.39 kg ha^{-1}. These results corroborates with the findings of Velmourougane (2016). Soil respiration (Reganold *et al.*, 1993) and dehydrogenase activity (Sihi *et al.,* 2017) of soil are representative of microbial activity in soil and this contribute to recycling of vital nutrients due to better soil microbial metabolic activities (Kirckner *et al.*, 1993). The significant increase in available N can also be attributed to substantial input of N from N-rich oil cakes and organic manures specifically leguminous green manure crops (Sihi *et al.*, 2017). Synchrony in the demand and rate of release of N from organic manures when compared to N from fertilizer, negligible loss of N through leaching and other transformations from organic manures which are managed properly contribute to available N in soils under organic management (Suja *et al.*, 2012). Lower soil organic matter content, reduced rhizosphere effect and lack of incorporation of organic inputs in the subsurface layers might be the reason to cause on available N content at 15-30 cm depth (Killham, 1994).

Within different zones, available N was generally found higher in hill zone area (Table 9). This might be due to the inherent soil quality as well as the increased SOM content of the region. Organic carbon status of the soil was taken as an index of available N status of soil. Majority of soils of Wayanad were having high available N status (Kerala State Planning board, 2013). The amount of available N, available P and organic matter of surface soil of hill zone suggest that a farmland or grassland or forest land use structure, from hill foot to hill top had a better capacity for soil conservation and retention of nutrients than other land use structures (Fu *et al.*, 2000).

5.1.2.4. Available Phosphorus

Perusal of data (Table 10) revealed that available P was found to be higher in soils under organic management at both depths. But the management practices did not create any significant difference in available P content. The range of variation between soils was found to be high, which is 7.7 to 58.2 kg ha^{-1} in surface soils from organic farms and 2.5 to 52.4 kg ha^{-1} in conventional soils. The range of values between the soils suggest the different management practices adopted by farmers of different farms. In a farm of Central zone where VAM was used, reported highest content of available P (58.24 kg ha^{-1}) in soil.

Comparisons made by Reganold *et al.*, (1993) and Drinkwater *et al.* (1995) also showed that P levels do not necessarily increase as a result of organic practices. But in the present study, although a significant difference was not obtained a higher mean available P was obtained in organic fields. This might be due to the solubilization of native P by organic acids during organic manure decomposition and increased mineralization of P from added organic manures due to higher microbial activity (Suja *et al.*, 2012).

5.1.2.5. Available Potassium

On scrutiny of the data from the Table 11, Fig. 3 revealed that a significantly higher amount of available K was found in soils of organic farms than conventional farms at 0-15 cm depth and Soil of hill zone was having higher available K and lower available K in soils of Southern zone. Surface soils of organic farms and conventional farms recorded a mean available K of 376.46 kg ha^{-1} and 230.72 kg ha^{-1} respectively.

K content as high as 0.5 per cent was reported by Kumar (2017) in kitchen waste inoculum compost. Higher K content in the organic manures like K rich compost, ash and coconut based crop waste, the extensive root system of green manure crop that extract K from the sub surface layers and the production of weak

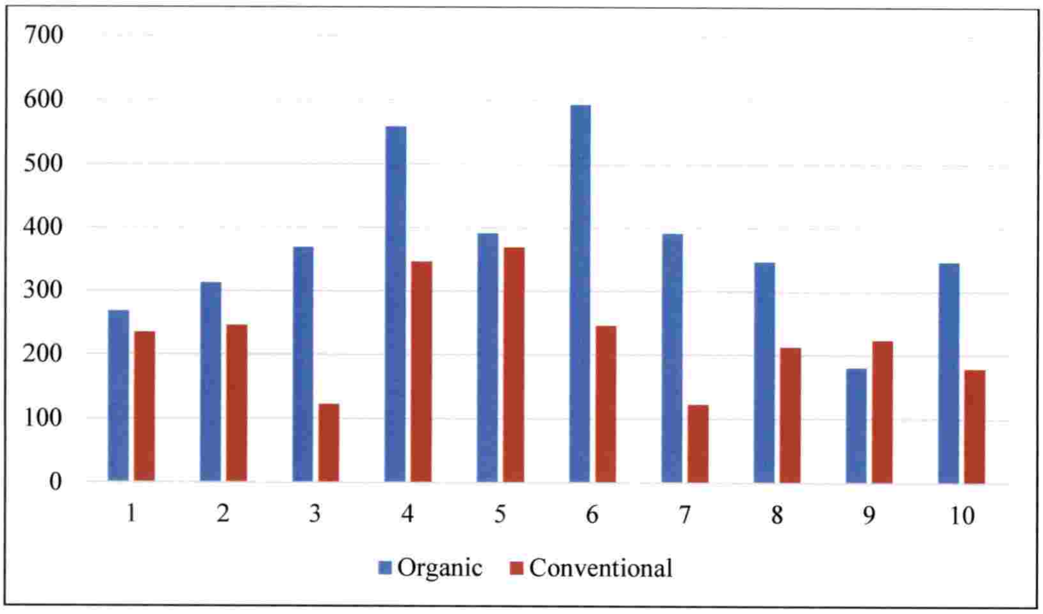

Fig. 3. Effect of organic and conventional management on available K (kg ha^{-1}) at 0-15 cm depth

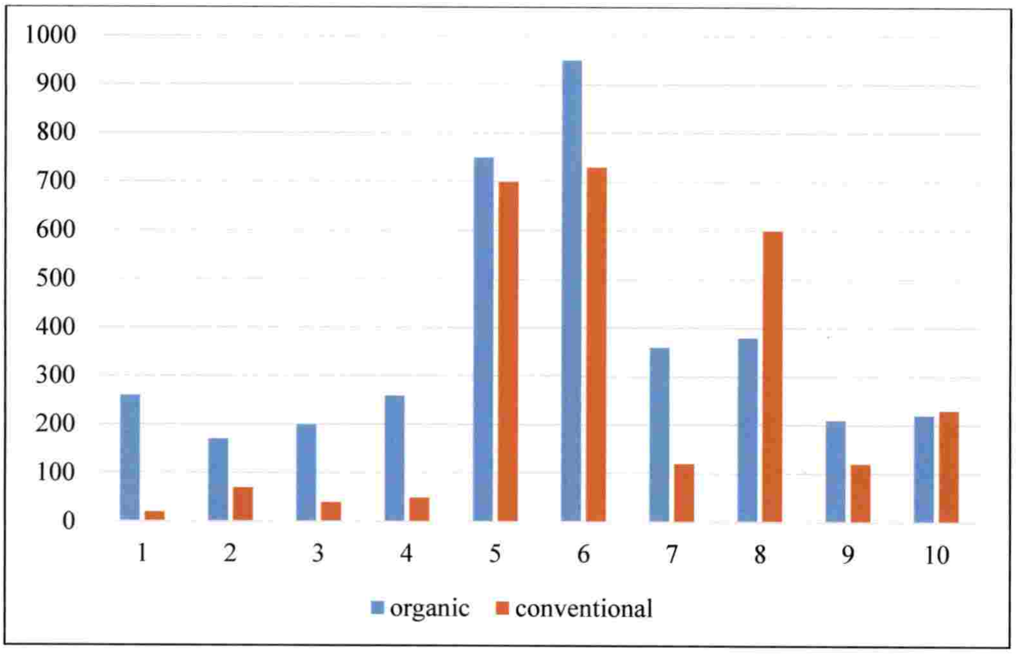

Fig. 4. Effect of organic and conventional management on available Ca (mg kg^{-1}) at 0-15 cm depth

organic acid during green manure decomposition that helped in its mineralization might have contributed to higher content of available potassium in organic field (Suja *et al.*, 2012). Inherent medium to high status of available K and organic matter of Wayanad soils, higher microbial activity as well as increased organic matter addition in hill zone made those soils rich in available K. Intensive cultivation practices coupled with use of manures low in K content might have resulted in less amount of available K in soils of Southern zone.

5.1.2.6. Available secondary nutrients

Available Ca was found significantly higher in surface soils of organic farms than soils of conventional farms (Table 12, Fig. 4) whereas no significant difference was noticed in its content in subsurface layer which can be attributed to the high organic matter status. Mean available Mg and S (Table 13, 14) was found higher in organic farms at both depths, but management practices did not significantly affected its content. The result was in confirmation with the findings of Clark *et al.* (1998).

Higher available Ca, Mg and S content can be attributed to higher organic matter content in soils of organic farms (Dhumgond *et al.*, 2017). Organic manures like FYM, green manure, cowpea and neem cake contain major as well as micro-nutrients (Suja *et al.*, 2012). Ca input through manure application might have resulted in higher Ca in soils of organic farms and low Mg concentration in applied manure and compost might have resulted in relatively low Mg content (Clark *et al.*, 1998).

5.1.2.7. Available micronutrients

Among available Fe, Mn, Zn and Cu, content of Cu and Zn were found significantly higher in surface soils of organic farms than soils of conventional farms (Tables 18, 19 and Fig. 5, 6). Management practices did not significantly affected Fe and Mn content in soils even though their content was found more in soils of organic farms than their conventional counterparts in most soil samples

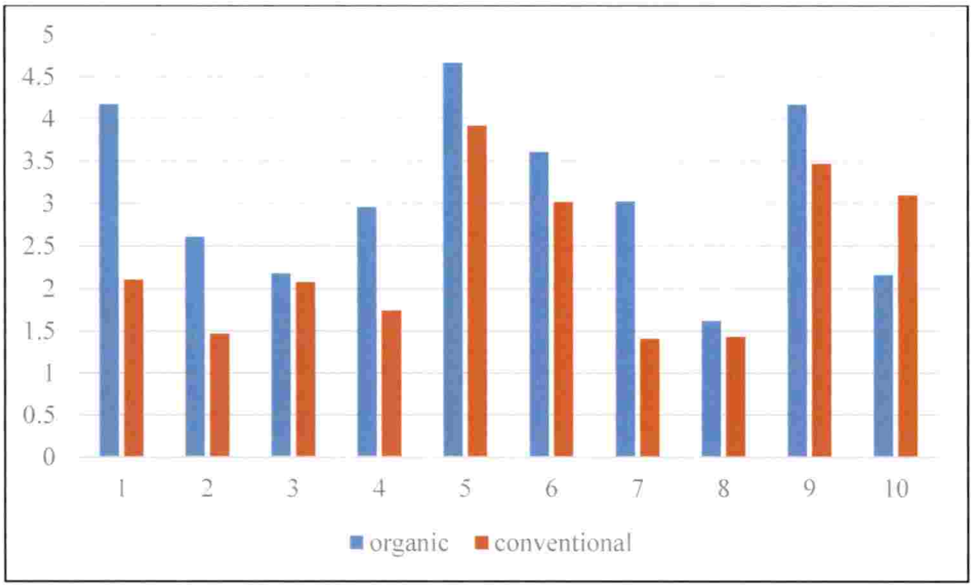

Fig. 5. Effect of organic and conventional management on available Zn (mg kg^{-1}) at 0-15 cm depth

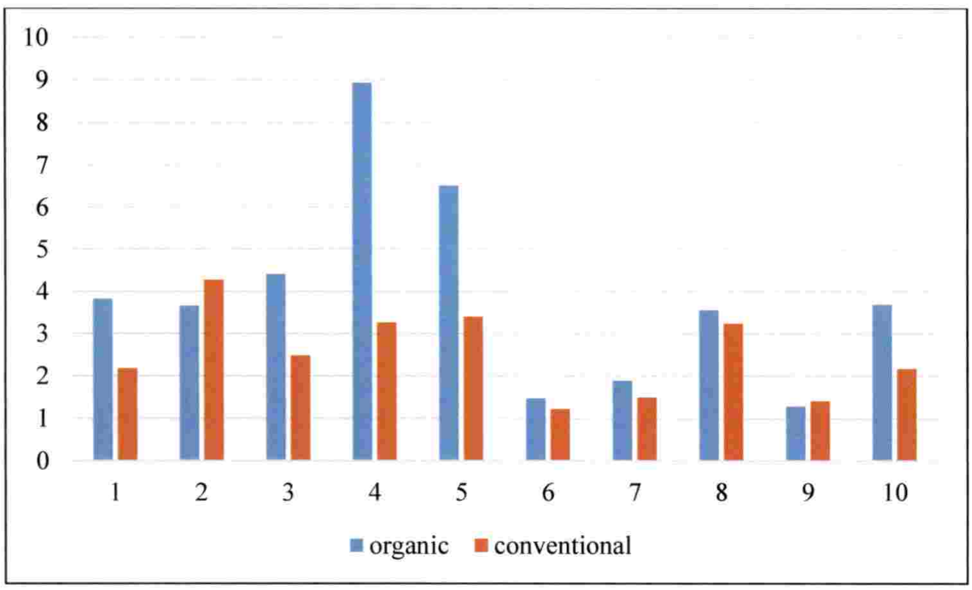

Fig. 6. Effect of organic and conventional management on available Cu (mg kg^{-1}) at 0-15 cm depth

(Tables 16, 17). The content of these micronutrients were in sufficient range in all soils analysed.

Analysis of cattle manure on fermentation showed the highest amounts of Zn, and Cu than sheep and poultry manure and the highest amount of Zn in soils was obtained when amended with cattle manure (Abu-Zahra *et al*., 2010). The mobility of Cu, Fe, Zn and Mn in organic soil decreases as a result of long term organic manure application since organic matter acts as a chelating agent and micronutrients show high affinity to organic matter resulting in stable bond formation and increase their availability on a long term basis (Sheoran *et al*., 2018). Higher microbial activity in soil contribute to recycling of macro as well as micro nutrients (Marinari *et al*., 2006).

5.1.2.8. Total and available heavy metals

Tables 20-22 reveal that among total Ni, Cd and Pb, content of Pb and Cd were found in traces which might be due to the lower rate of input used and the inputs used are not contaminated. In addition, the climate and soil conditions may not favour retention of heavy metals in soil (Alloway, 1990). Total Ni was found more in soils of organic farms than soils from conventional farms even though no significant difference was observed. In soils of southern zone total Ni was found in traces. From Tables 23-25 it was clear that except for available Ni in hill zone soils, other metals were found in traces in all soils indicating that type of farming whether organic or conventional is not contributing towards heavy metal build up in soil under Kerala conditions.

The metals in soils were located on the stable soil phases and it would not be easily released unless there are changes in environmental conditions (Diouf, 2016). Presence of available Ni in soils of hill zone might be due to the influence of parent material as the parent material largely influences heavy metal content in many soil types (Palumbo *et al*., 2000 and Parth *et al*., 2011).

5.1.3. Effect on biological properties

5.1.3.1. Soil organic matter

SOM content was recorded to be higher in organic soil than in conventional soil but no significant difference was observed at both 0-15 cm and 15-30 cm depths. The results are in conformity with the findings of Gosling and Shepherd (2002) and Hathaway-Jenkins *et al.* (2010). Higher yield obtained in conventional farms is indicative of more root biomass and increased rhizosphere effect which can contribute to build up of SOM even though manure addition is less in conventional farms compared to organic farms. This balance maintained between native and added organic matter might be the reason for non-significant difference in SOM content between soils of organic and conventional farms.

Observed difference in SOC contents between organic and conventional system after about 12.5 years of management practices (23.45%) agree with the proposed rate of increase in SOC level by Leifeld and Fuhrer (2010) which is about 2.2% on average annually. Soil organic matter was found to be increasing only a few tenths of a percent even after10 years of organic management (Wander *et al.*, 1994). Shepherd *et al.* (2003) reported that soil type, long-term cropping and other history (i.e. return of crop residues), topography, climate and stocking density affect the SOM content of all soils. Total SOM levels or soil carbon content change occurs slowly in arable conditions (Johnston, 1986). Also, at least 65 t/ ha/yr of organic matter should be applied to exhibit a significant difference in organic matter content (Hathaway-Jenkins *et al.*, 2010).

In Palakkad and Wayanad soil of organic farms where many perennial trees are grown and tree loppings as well as crop residues were incorporated, a higher amount of organic matter (Table 5) was observed. Also cattles were found more in number in those farms. This might have contributed to higher organic matter content in these regions. Yield of crops must also be considered since they contribute to organic matter addition (Gosling and Shepherd, 2002). But since organic matter addition to organic farms are more than conventional farms due to addition of lot of organic manures, SOM is higher in organic system. Moreover, mechanical weed control used more often in organic field than in conventional field since weedicides are not allowed in organic system result in a high short-term decomposition of organic matter (Marinari *et al.*, 2006). Nevertheless, the level of soil's organic matter content is primarily related to the site-specific conditions and individual activities of farmer (Stolze *et al.*, 2000).

5.1.3.2. Dehydrogenase activity

Dehydrogenase activity is a direct measure of soil microbial activity. Long-term application of organic amendments have made a considerable influence on the activity of dehydrogenase enzyme at both depths (Table 26, Fig.7, 8) and this is in confirmation with result obtained by Sihi *et al.* (2017). Highest dehydrogenase activity was observed in soils of hill zone whereas lowest activity was found in soils of southern zone. Higher soil organic matter content as well as the favourable microclimate might have helped in increased microbial acivity in hilly areas (Wayanad).

The higher dehydrogenase enzyme activity in organic soil can be attributed to higher oxidation or decomposition of organic matter owing to the supply of large quantities of organic sources of nutrients to replace the chemical fertilizers (Suja, 2013) and also due to increase in release of root exudates as a consequence of improved crop growth creating a conducive environment for microbial growth (Burns *et al.*, 2013). Generally a higher soil organic matter content contribute more to microbial growth but here, even though no significant difference was observed in SOM content, enzyme activity was found significantly higher. This is because microbiological properties and enzyme activities are soil indicators which are more sensitive to changes that occur under different farming systems (Bergstrom *et al.*, 1998 and Marinari *et al.*, 2006).

5.1.3.3. Soil respiration

Soil respiration is an indication of the biological activity of soil organisms, including plant roots, microbes, and soil animals as it is the measure of

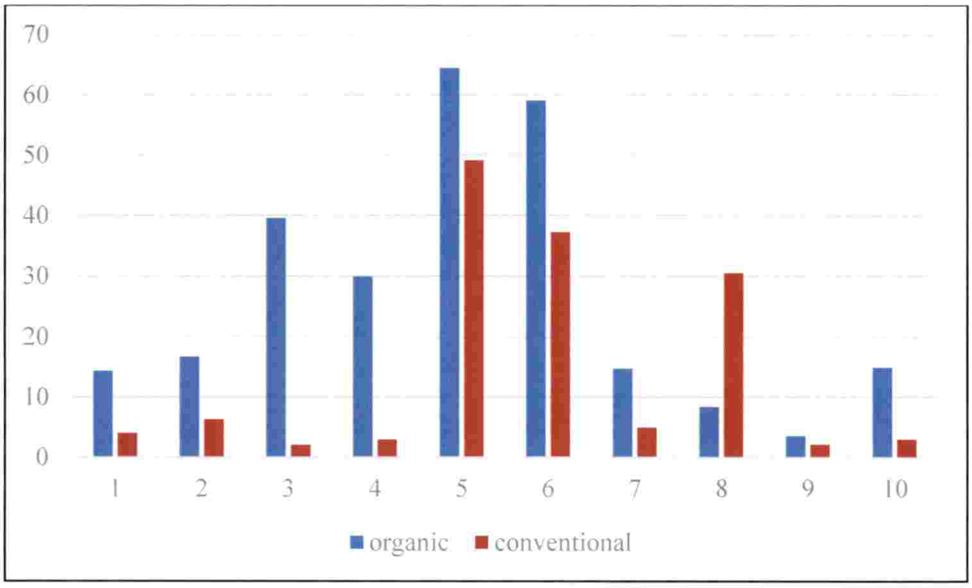

Fig. 7. Effect of organic and conventional management on dehydrogenase enzyme (μg of TPF g^{-1} soil 24 h^{-1}) at 0-15 cm depth

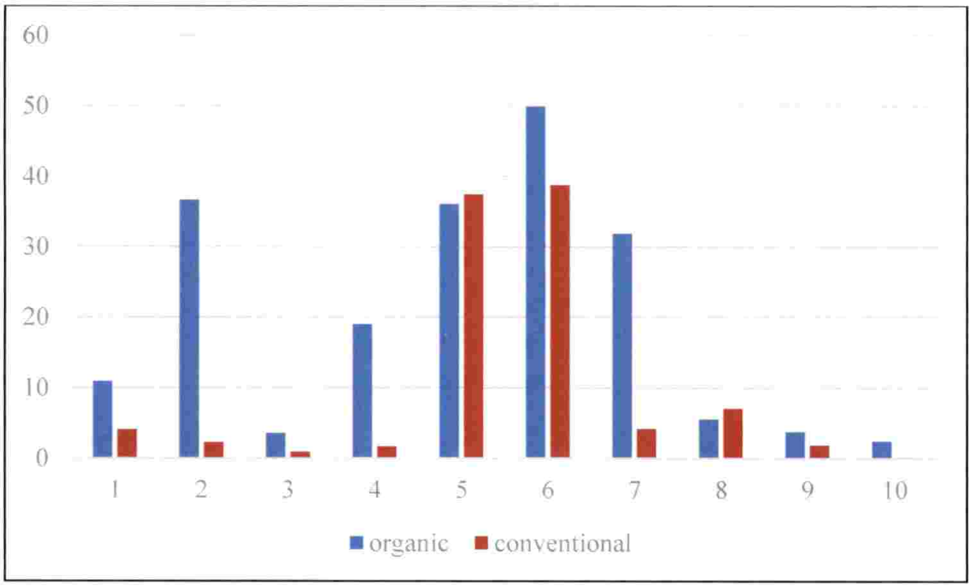

Fig. 8. Effect of organic and conventional management on dehydrogenase enzyme (μg of TPF g^{-1} soil 24 h^{-1}) at 15-30 cm depth

CO_2 produced by these organisms (Phillips and Nickerson, 2015). Mean respiratory activity of surface soils of organic and conventional farms was 10.25 and 7.94 mg CO_2 100 g^{-1} soil 24 h^{-1} respectively (Table 27, Fig. 9). A significantly higher soil respiratory activity in soil of organic farm at 0-15 cm depth point out the soil health promoting functions of organic farming system on microbial activity (Velmourougane, 2016). This increase in soil of organic farm can be attributed the long-term effect of addition of organic matter in the form of organic compost and crop residues which stimulated the multiplication of heterotrophic microorganisms (da Rocha Silva *et al.*, 2018).

As reported by Fang and Moncrieff (2005), soil respiration reduced as depth increased. No significant difference was observed in respiratory activity at 15-30 cm depth (Fig. 10) which was similar to the finding of Velmourougane (2016).

5.1.3.4. Earthworm and arthropod count

From Table 31, Fig.11, 12 it was clear that earthworm as well as soil arthropods were positively influenced by the management practices. The increased earthworm activity observed in soils of organic farms can be attributed to higher soil organic matter content and other conditions conducive for growth and reproduction of earthworms (Pfiffner and Mäder, 1997). Also higher infiltration rate in organic fields favoured higher earthworm activity (Liebig and Doran, 1999). Variation in number of earthworms within a zone could be because of the difference in soil type, condition and management practices (Tchernyshev *et al.*, 2019). Mechanical disturbance as well as reduced organic matter availability negatively affect earthworm populations. Earthworm populations can be negatively affected by the use of certain pesticides as well as high levels of inorganic fertilizers (Pulleman *et al.*, 2003).

5.1.3.5. Bacteria, Fungi and Actinomycetes

As seen from Tables 28-30, bacterial, fungal and actinomycetes count were significantly influenced by management systems and soils of organic farms were found to have significantly higher bacterial, fungal and actinomycetes population

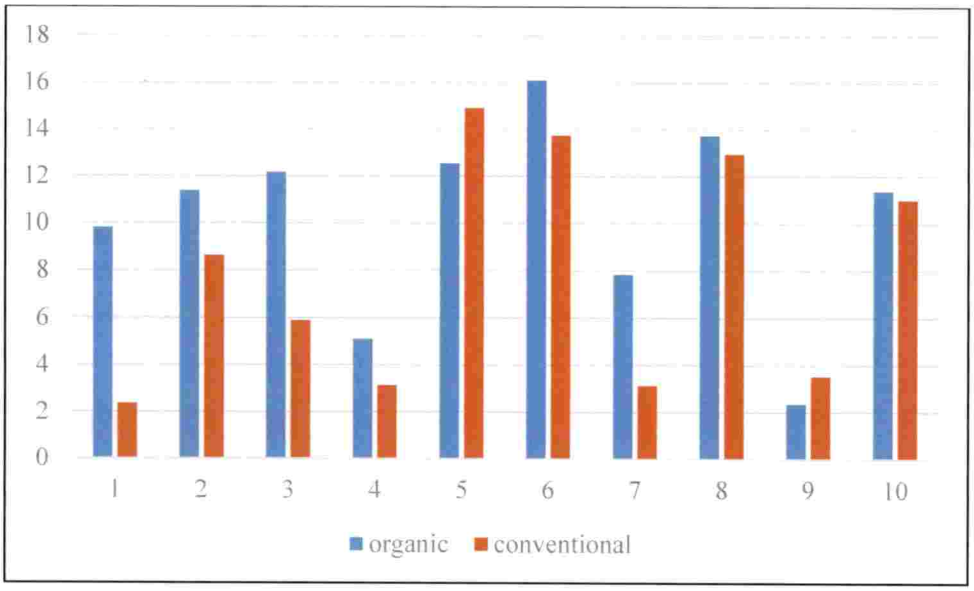

Fig.9. Effect of organic and conventional management on respiratory activity ($mg\ CO_2\ 100\ g^{-1}$ soil $24\ h^{-1}$) at 0-15 cm depth

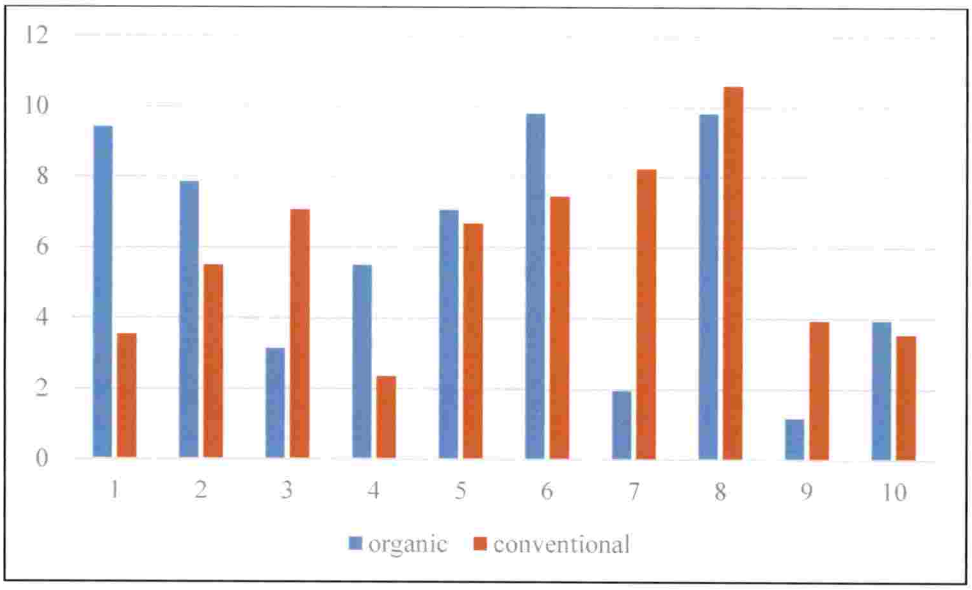

Fig.10. Effect of organic and conventional management on respiratory activity ($mg\ CO_2\ 100\ g^{-1}$ soil $24\ h^{-1}$) at 15-30 cm depth

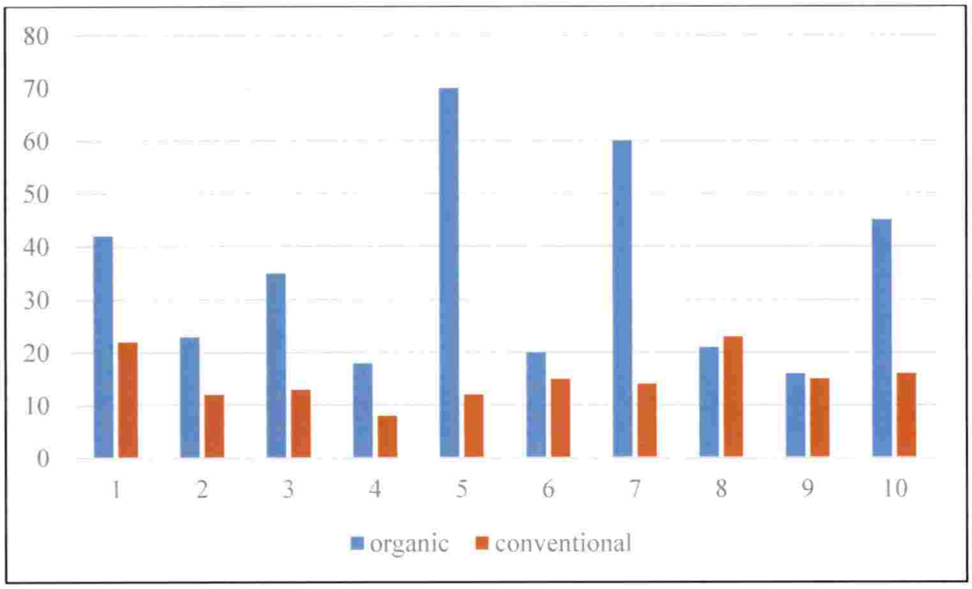

Fig. 11. Effect of organic and conventional management on earthworm population, numbers m^{-3}

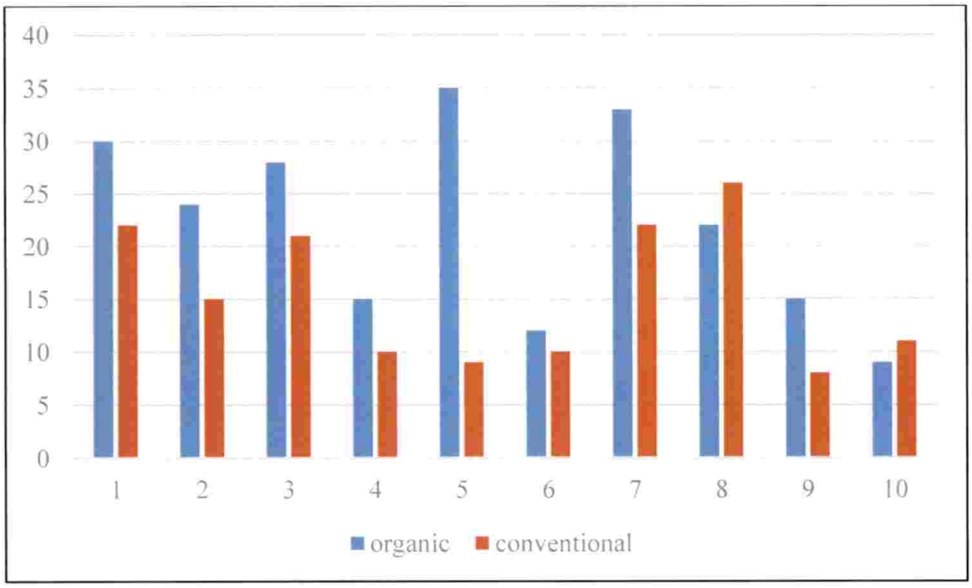

Fig.12. Effect of organic and conventional management on soil arthropod population, numbers m^{-3}

than soil of conventional farms at both 0-15 and 15-30 cm depths. The highest count of bacteria, fungi and actinomycetes noted in the surface soil of organic farms were 8.63, 6.03 and 4.56 log cfu ml^{-1} respectively (Fig. 13, 15, 17). The highest count of bacteria, fungi and actinomycetes noted in the sub surface soil of organic farms were 8.44, 5.83 and 4.52 log cfu ml^{-1} respectively (Fig.14, 16, 18).

Increased organic matter and biological activity in soils might be due to the use of recycled organic wastes (Bulluck *et al.*, 2002). The quality and quantity of different inputs used such as animal manure, green manure etc. could impact microbial abundance and activity in organic production system (Tu *et al.*, 2006). Microbiological properties are the most sensitive soil indicators to changes that occur under different farming systems (Bergstrom *et al.*, 1998 and Marinari *et al.*, 2006).

5.1.4. Soil quality index

Soil health plays a key role in Earth's life support system and therefore viewed as the component of soil quality and ecosystem health that reflects the properties of soil as a living system. Soil quality is defined as degree of fitness of soil for a specific use or capacity of soil to function (Carter *et al.*, 1997 and Karlen *et al.*, 1997). In recent years soil health and soil quality have been used synonymously (Harris and Romig, 2006).

From Table 32, Fig.19, 20, it was evident that a maximum index value of 61.1 was got in 50 per cent of the surface soils from organic farms and in case of soils from conventional farms, only hill zone soils were found to have that index. This might be due to the inherent soil properties of hill zone soil, increased depositions, reduced mineralization, type of vegetation and microclimate (Nair *et al.*, 2007). And at subsurface layer except for soil samples from 2 locations, in all other locations, index was found more for soil from organic farms. More number of chemical properties were considered in calculating index, but significant differences between soils of organic and conventional were found in case of

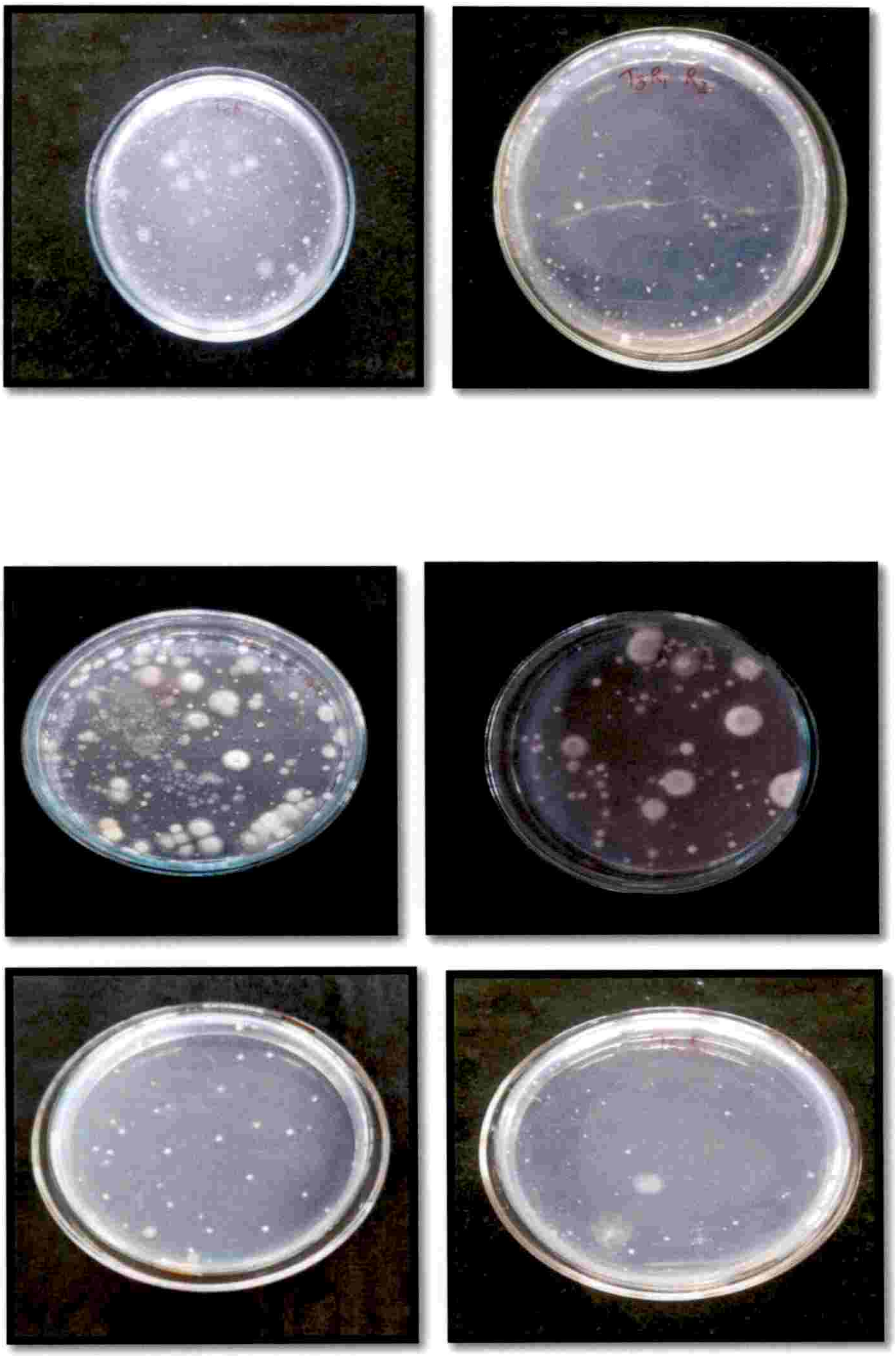

Plate 6: Bacterial, fungal and actinomycetes count of organic and conventional farm

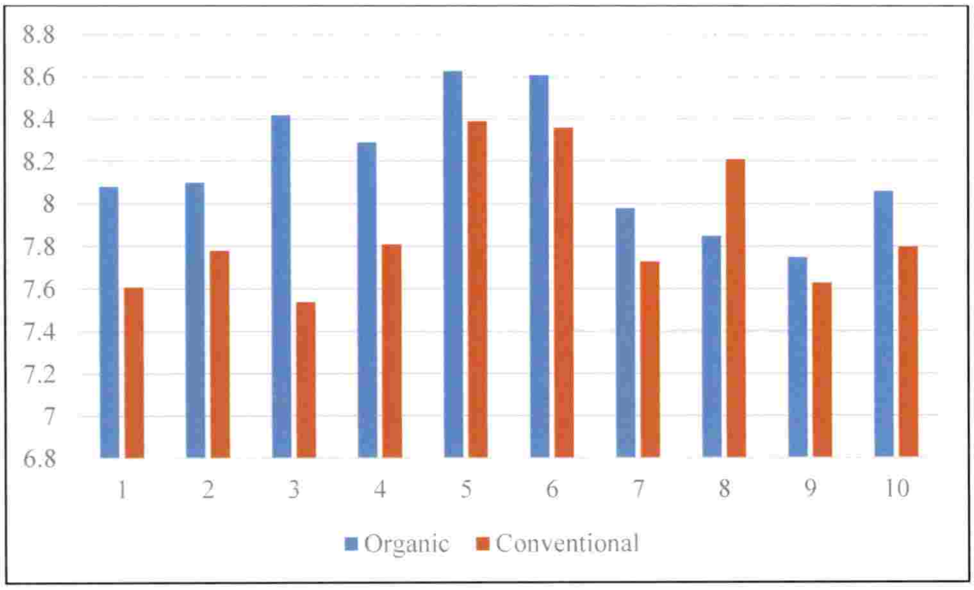

Fig. 13. Effect of organic and conventional management on bacteria count (log cfu ml^{-1}) at 0-15 cm depth

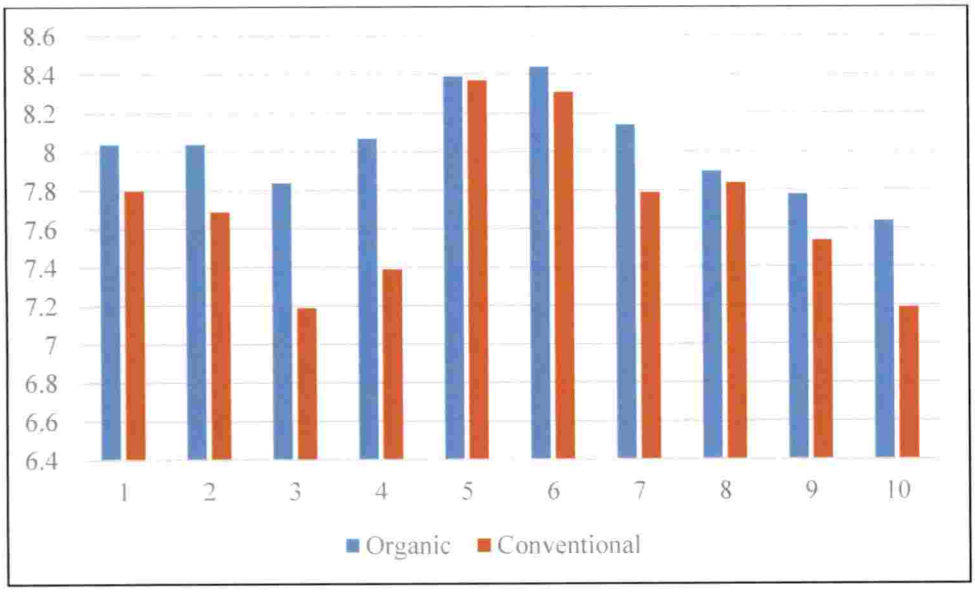

Fig. 14. Effect of organic and conventional management on bacteria count (log cfu ml^{-1}) at 15-30 cm depth

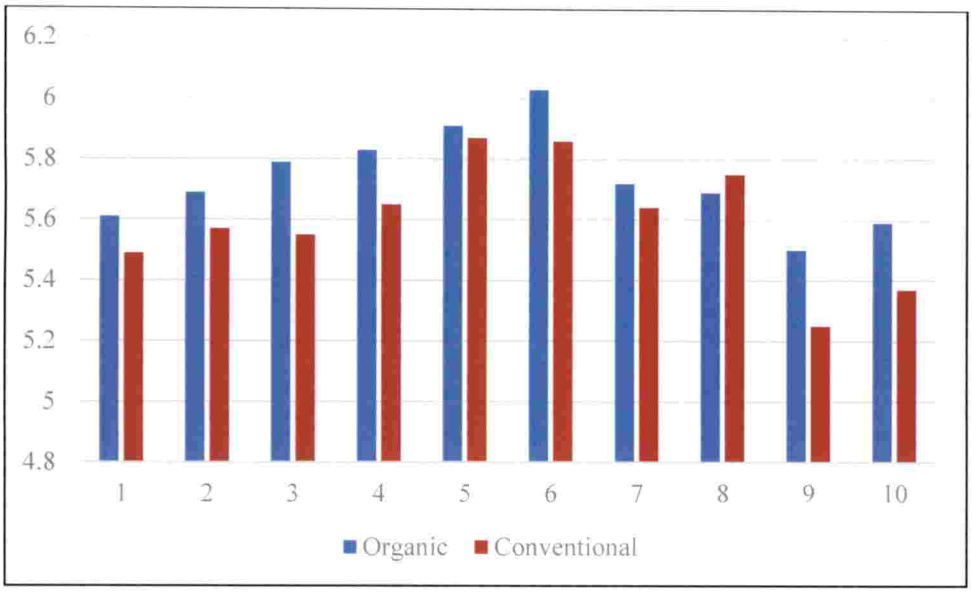

Fig. 15. Effect of organic and conventional management on fungi count (log cfu ml^{-1}) at 0-15 cm depth

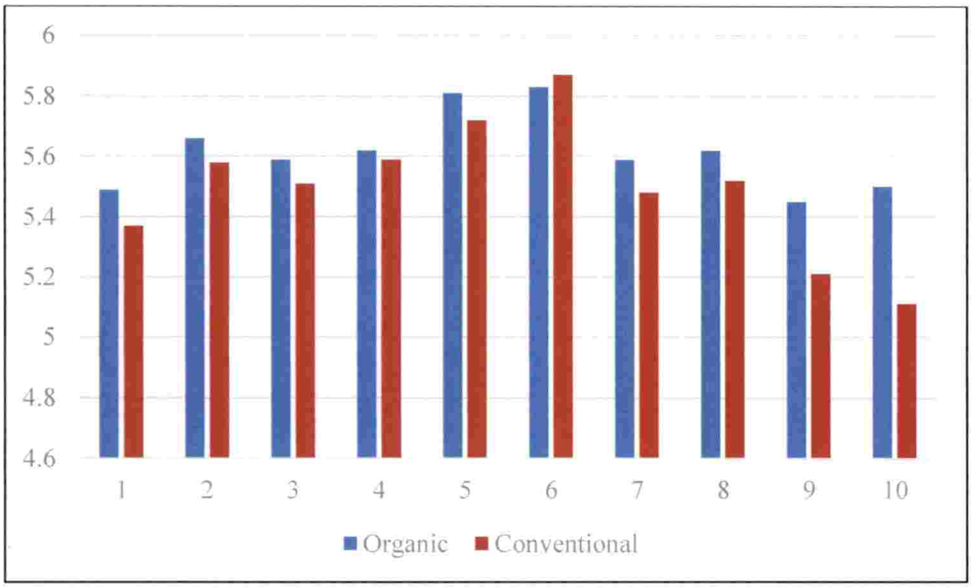

Fig. 16. Effect of organic and conventional management on fungi count (log cfu ml^{-1}) at 15-30 cm depth

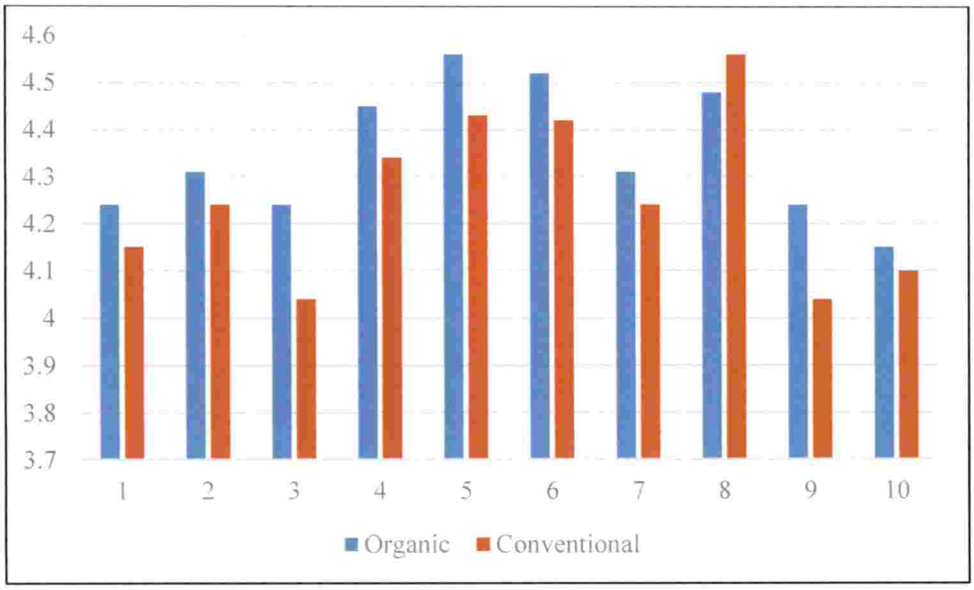

Fig. 17. Effect of organic and conventional management on actinomycetes count ($\log$ cfu ml^{-1}) at 0-15 cm depth

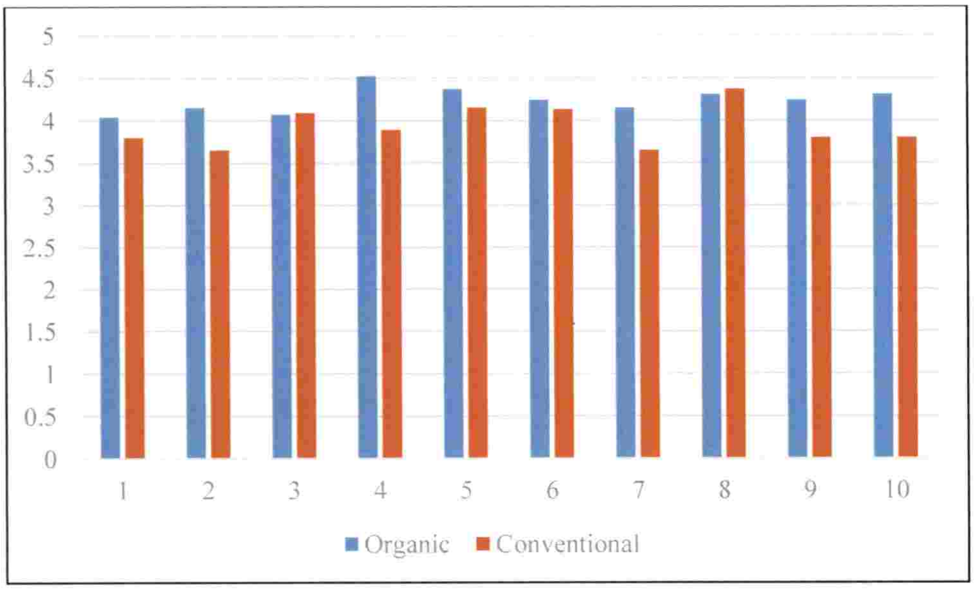

Fig. 18. Effect of organic and conventional management on actinomycetes count, ($\log$ cfu ml^{-1}) at 15-30 cm depth

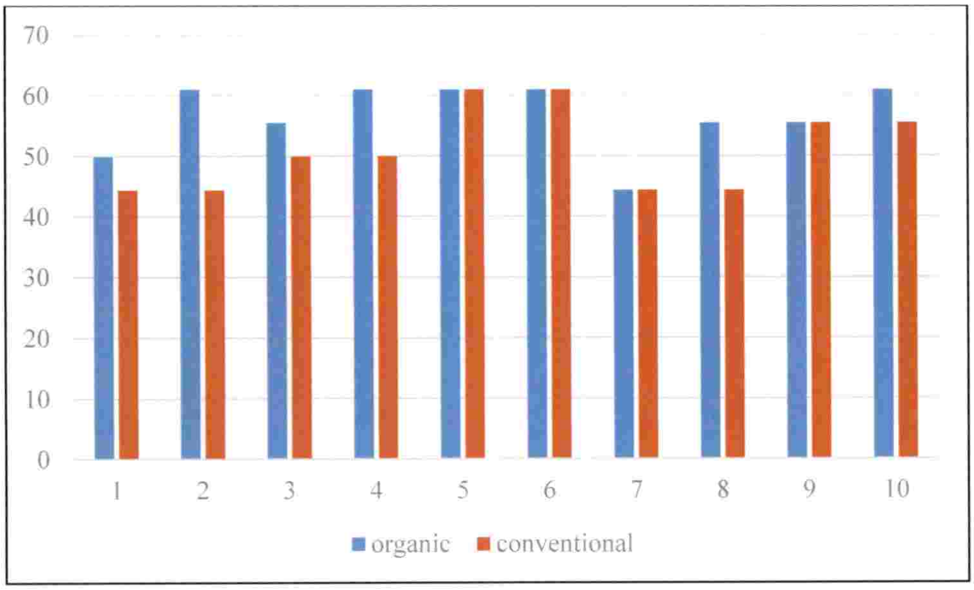

Fig. 19. Soil quality index of surface soils, per cent

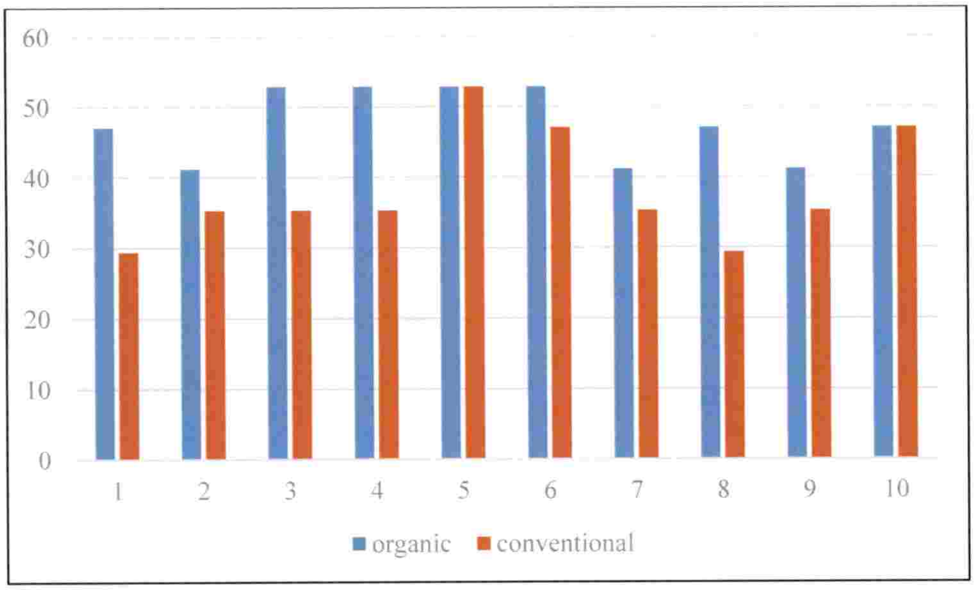

Fig. 20. Soil quality index of subsurface soils, per cent

biological properties which are lesser in number. This might be the reason of lesser difference in soil quality obtained between organic and conventional soil samples.

5.2. HEAVY METAL / MICRONUTRIENT CONTENT IN INPUTS

From Table 33, 34, it was clear that the analysed inputs used in organic as well as conventional farms are not causing any threat to environment. And after 12-15 years of farming also, the content of heavy metals (Pb, Cd and Ni) in soil were also not causing any threat and are within the safe limit.

Available Zn in all soils analysed were in sufficient range. Even though the Zn content in manures were found lesser than those in fertilizers, large quantities of application of these might cause problem depending upon the crop that is grown in these fields as seen in the case of amaranthus in the present study.

5.3. EFFECT OF ORGANIC AND CONVENTIONAL MANAGEMENT PRACTICES ON HEAVY METAL CONTENT IN PLANT PRODUCE

Among analysed heavy metals, apart from Zn and Cu other heavy metals were found in traces (Tables 35, 36). Zn content in amaranthus from both organic and conventional systems were found exceeding the safety standard limit. Zn content in plant produce was found significantly affected by management practices. Głodowska and Krawczyk, (2017) reported that in consequence to the higher level of Zn in soil of organic farm, an elevated level Zn was also recorded in the organic vegetables. Similarly the present study revealed that there was a significant positive correlation in the available Zn in soil and Zn in plant produce from both conventional and organic management (Tables 37, 38).

As reported by Worthington, (2001) rather than the cultivation system, Cu accumulation was found depending mainly on the type of vegetable. *i.e.*, Cu content in plant produce was not found significantly affected by management practices. Organic fertilizers with high content of copper can be used safely into soil since no correlation was obtained between dry biomass of oats and available Cu in soil (Hanc *et al.*, 2008).

As the content of Ni, Pb and Cd in soil as well as in inputs were not high these elements were found in traces in plant produce also. A higher level of Zn in amaranthus might be because of the ability of amaranthus to accumulate heavy metals in them. Both green and red amaranthus species showed an affinity for Ni and Cd with moderate to high levels detected in their leaves, respectively Chunilall *et al.* (2005). Various species of amaranthus have been reported to accumulate heavy metals in them (Oluwatosin *et al.,* 2009; Atayese *et al.,* 2010 and Khoramnejadian and Saeb, 2015).

Summary

6. SUMMARY

An investigation was made to assess and compare the physical, chemical and biological properties of soils under certified organic and conventional management in Kerala comprising of Northern, Hilly, Central and Southern zones. The heavy metal status (Cd, Pb, Ni, Cu and Zn) of the inputs as well as produce of 10 crops each from organic and conventional farms were assessed. The salient results emerged from the study are summarised in this chapter.

The influence of organic and conventional management practices on soil properties can be summarised as follows.

- Bulk density of soil was not seen significantly influenced by management practices. Mean value of bulk density of surface soil samples from 10 organic farms (1.29 Mg m^{-3}) was found lower than that from soils of conventional farms (1.37 Mg m^{-3}) which is an indicative of good soil structure in organic fam.
- Mean water holding capacity of soils of organic farms was higher than soils of conventional farms at 0-15 cm and 15-30 cm. But no significant difference was noticed at both depths. Highest water holding capacity (57.07 per cent) was recorded in soil from organic farm in Palakkad and lowest in soil from conventional farm of the Southern Zone (24.02 per cent).
- Soil organic matter was also found higher in soils of organic farms than in soils of conventional farms, though no significant difference was noticed in its content at both depths. At 0-15 cm depth, SOM was found highest in soils of hill zone (6.32 per cent) and lowest in southern zone (1.71 per cent). SOM reduced as depth increased.
- pH of surface soil was significantly influenced by management practices and was found more acidic in soils under organic management than in soils under conventional management at both depths. Mean pH of 5.33 and 5.64 were recorded in surface soils of organic farms and conventional farms respectively.

- Electrical conductivity (soluble salt concentration) was also found more in soils of organic farms. But management practices did not create any significant influence in electrical conductivity at both depths.
- Available N was significantly higher in surface soils of organic farms (319.87 kg ha^{-1}) than in conventional farms (253.39 kg ha^{-1}). Even though a higher available N was recorded in soils of organic farms (260.92 kg ha^{-1}) than soils of conventional farms (238.34 kg ha^{-1}) at 15-30 cm depth also, no significant difference was noticed.
- Available P was not significantly influenced by management practices but a higher mean available P was recorded in soils of organic farms than in conventional farms at both depths. As depth increased content of available P reduced.
- A significantly higher available K was recorded in surface soils of organic farms (376.46 kg ha^{-1}) than conventional farms (230.72 kg ha^{-1}). At 15-30 cm depth also available K was higher in soils of organic farms. But no significant difference was noticed in its content. In surface soil, highest available K was recorded in soil of hill zone (593.6 kg ha^{-1}) and lowest in soil of southern zone (123.2 kg ha^{-1}).
- Available Ca was significantly higher in surface soils of organic farms (376 mg kg^{-1}) than conventional farms (230.72 mg kg^{-1}). At 15-30 cm depth also available Ca was more in soils of organic farms than in conventional farms. But no significant difference was noticed.
- Available Mg was not significantly influenced by management practices. But a higher available Mg was recorded in soils of organic farms than that of conventional farms at both depths.
- Available S was also found higher in soils of organic farms than conventional farms at both depths. But no significant difference was noticed in its content between two management systems. Available B also showed a similar trend.
- Among available Fe, Mn, Zn and Cu, only content of available Zn and Cu was found significantly higher in surface soils under organic management.

Mean available Zn in surface soils of organic and conventional farms were 3.11 and 2.38 mg kg^{-1} respectively. Surface soils of organic and conventional farms recorded 3.93 and 2.52 mg kg^{-1} available Cu respectively. At 15-30 cm depth all micronutrients were higher in soils under organic management, but no significant difference was noticed.

- The study also revealed that total as well as available Cd and Pb were present only in traces in the agricultural soils of Kerala. Total Ni was in the range of 16.6 to 93.1 mg kg^{-1} in soils of organic farms and 24.3 to 70.5 mg kg^{-1} in conventional soils at 0-15 cm depth and 9.1 to 78.4 mg kg^{-1} and 8.2 to 65.7 mg kg^{-1} in soils of organic and conventional farms at 15-30 cm depth respectively. It was found only in traces in soils of Southern Zone. Available Ni was found in traces in all soils except for soils of Hilly zone and higher content was recorded in soils of organic farms.
- Bacterial population was found significantly higher in soils of organic farms than soils of conventional farms at both depths. Surface soil of organic and conventional fields recorded 8.18 and 7.89 log cfu ml^{-1} bacteria respectively. At 15-30 cm depth, 8.03 and 7.71 log cfu ml^{-1} bacteria population was recorded in soils of organic and conventional farms respectively.
- A significantly higher population of fungi was found in soils of organic farms than in conventional farms at both 0-15 cm and 15-30 cm depths. Mean fungi population of surface soils of organic and conventional farms was 5.74 and 5.6 log cfu ml^{-1} respectively. And highest population of fungi was observed in soil of organic farm from Wayanad (6.03 log cfu ml^{-1}).
- Actinomycetes population was also found significantly influenced by management practices and was found higher in soils of organic farms than conventional farms at both depths. Mean actinomycetes population of surface soils of organic and conventional farms was 4.35 and 4.26 log cfu ml^{-1} and at 15-30 cm mean value recorded was 4.24 and 3.93 log cfu ml^{-1} in soils under organic and conventional management respectively.

- Number of earthworms from 1 cubic metre soil excavated were also found significantly higher in soils of organic farms than in conventional farms. Mean earthworm population of organic and conventional farms were 35 and 15 numbers m^{-3} respectively.
- Mean arthropod number of organic and conventional farms were 22.3 and 15.4 numbers m^{-3} respectively and significant difference in arthropod number was recorded between organic and conventional farms.
- Dehydrogenase enzyme activity which is a direct measure of soil microbial activity was significantly higher in soils of organic farms than conventional farms at both depths. A mean value of 26.6 and 14.27 µg of TPF g^{-1} soil 24 h^{-1} was recorded for surface soils of organic and conventional farms respectively. Highest activity was observed in soils of hill zone and lowest in soil of southern zone at both depths.
- Respiratory activity which is an indication of the biological activity of all soil organisms including plant roots was found significantly higher in soils of organic farms (10.25 mg CO_2 100 g^{-1} soil 24 h^{-1}) than conventional farms (7.94 mg CO_2 100 g^{-1} soil 24 h^{-1}) at 0-15 cm depth and at 15-30 cm also activity was found higher in organic farms than conventional farms, but no significant difference was noticed.
- The study revealed that in general, soil quality was improved in farms where organic management was practiced for more than 12 years and biological properties were found most sensitive to changes due to the management practices adopted.

Analysis of heavy metal content in inputs of organic and conventional farming revealed the following:

- Except for the content of Cu in fertilizers and manures, no other heavy metals were observed to be significantly different in manures and fertilizes.
- Among the heavy metals, Zn was found highest in fertilizers and Cu in manures.
- All the heavy metals were found within the safe limit.

The influence of organic and conventional management practices on heavy metal content (Zn, Cu, Pb, Ni and Cd) in plant parts can be summarised as follows.

- Except for Zn and Cu, other heavy metals were found in traces in 10 samples each of plant produce which were collected from organic and conventional farms. Zn content in amaranthus from both organic and conventional farm was found above food safety standard set by WHO. Among the produce of crops analysed, amaranthus was found to have highest content of Zn and Cd under both management and Ni under conventional management.
- Zn content in plant produce was found significantly affected by management practices and was found higher in plant produce collected from organic farm. Zn in plant produce was having a positive correlation with available Zn in soil.

So from the study it can be concluded that, many of the physical and chemical properties of the soil did not show any significant increase due to organic farming over conventional farming. They were water holding capacity, pH, EC, available P, Mg, S and some micronutrients. However all biological properties- microbial count, dehydrogenase, respiratory activity, earthworm and arthropod count were significantly higher in soils of organic farms than conventional farms. Soil quality was found higher in hill zone soils compared to other zones irrespective of the management practices. Though not significant a slight increase in soil quality was observed in organic farms than in conventional farms in northern, central and southern zones of Kerala. Heavy metals in plant produce analysed were also very much within the safe limit of food safety standards except for Zn content in amaranthus from both organic and conventional farms. Heavy metals in the inputs used were also within the permissible limit. Significantly higher biological properties in soils of organic farms indicate the scope to assess the extent to which biological properties can contribute to enhance physical and chemical properties in the long run as a future thrust of research.

References

REFERENCES

Abu-Zahra, T. R., Abubaker, S. M., Tahboub, A. B., and Al-Abbadi, A. A. 2010. Effect of organic matter sources on micronutrients and heavy metals accumulation in soil. *Food Agric. Environ.* 8: 1199-1202.

Acton, D.F. and Padbury, G.A. 1993. A conceptual framework for soil quality assessment and monitoring. In: Acton, D.F. (ed.), *A Program to Assess and Monitor Soil Quality in Canada: Soil Quality Evaluation Program Summary (Interim).* Centre for Land and Biological Resources Research Contribution No.93-94, Research Branch, Agriculture and Agri-Food Canada, Ottawa, pp. 2-7.

Alloway, B.J. 1990. *Heavy Metals in Soils*. Blackie and Son Ltd, Glasgow and London, 339p.

Amacher, M. C., O'Neil, K. P., and Perry, C. H. 2007. *Soil vital signs: A new Soil Quality Index (SOI) for assessing forest soil health*. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station, 12p.

Anderson, J. P. 1982. Soil respiration. In: *Methods of soil analysis. Part 2. Chemical and microbiological properties*, (methods of soil an 2), pp. 831-871.

AOAC. 1980. *Official and Tentative Methods of Analysis*. Association of Official Agricultural Chemists, Washington, 721p.

Araujo, A., Leite, L., Santos, V., and Carneiro, R. 2009. Soil microbial activity in conventional and organic agricultural systems. *Sustain.* 1(2): 268-276.

Atayese, M. O., Eigbadon, A. I., Oluwa, K. A., and Adesodun, J. K. 2010. Heavy metal contatimination of Amaranthus grown along major highways in Lagos. *Afr. Crop Sci. J.* 16(4): 23-25.

Atlas, R. M. and Parks, L. C. 1993. *Handbook of Microbiological Media*. CRC Press, Inc. London, 529p.

Awashthi, S.K. and Bhatnagar, J. P. 2000. *Prevention of Food Adulteration Act No. 37 of 1954. Central and State Rules as Amended for 1999, 3rd ed.* Ashoka Law House, New Delhi, 71p.

Bergstrom, D. W., Monreal, C. M., and King, D. J. 1998. Sensitivity of soil enzyme activities to conservation practices. *Soil Sci. Soc. Am. J.* 62: 1286–1295.

Bhogal, A., Nicholson, F. A., and Chambers, B. J. 2009. Organic carbon additions: effects on soil bio-physical and physico-chemical properties. *Eur. J. Soil Sci*. 60(2): 276-286.

Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L., and Clark, F.E. 1965. *Methods of Soil Analysis*. American Society of Agronomy, Madison, USA, 1569p.

Blaise, D., Rupa, T. R., and Bonde, A. N. 2004. Effect of organic and modern method of cotton cultivation on soil nutrient status. *Comm. Soil Sci. Plant Anal*. 35(9-10): 1247-1261.

Bray, R. H. and Kurtz, L.T. 1945. Determination of total organic and available forms of phosphorous in soils. *Soil Sci*. 59: 39-45.

Bulluck, L. R., Brosius, M., Evanylo, G. K., and Ristaino, J. B. 2002. Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. *Appl. Soil Ecol.* 19(2): 147-160.

Burns, R. G., de Forest, J. L., Marxsen, J., Sinsabaugh, R. L., Stromberger, M. E., and Wallemstein, M. D. 2013. Soil enzymes in a changing environment: Current knowledge and future directions. *Soil Biol. Biochem*. 32: 1547-1559.

Cardoso, P. C., Cândido, F. G., Cardoso, L. M., Costa, N. M., Martino, H. S., and Pinheiro-Sant'Ana, H. M. 2015. Comparison of mineral and trace element contents between organically and conventionally grown fruit. *Fruits*. 70(1): 29-36.

Carter, M.R., Gregorich, E.G., Anderson, D.W., Doran, J.W., Janzen, H.H., and Pierce, F.J. 1997.Concept of soil quality and their significance. In: Gregorich, E.G. and Carter, M. (eds), *Soil Quality for Crop Production and Ecosystem Health*. Elsevier Science Publishers, Amsterdam, Netherlands, pp. 1-19.

Casida, L. E., Klein, D. A., and Santoro, T. 1964. Soil dehydrogenase activity. *Soil Sci.* 98: 371-376.

Celik, I., Gunal, H., Budak, M., and Akpinar, C. 2010. Effects of long-term organic and mineral fertilizers on bulk density and penetration resistance in semi-arid Mediterranean soil conditions. *Geoderma*. 160(2): 236-243.

Chunilall, V., Kindness, A., and Jonnalagadda, S. B. 2005. Heavy metal uptake by two edible Amaranthus herbs grown on soils contaminated with lead, mercury, cadmium, and nickel. *J. Environ. Sci. Health*. 40(2): 375-384.

Clark, M. S., Horwath, W. R., Shennan, C., and Scow, K. M. 1998. Changes in soil chemical properties resulting from organic and low-input farming practices. *Agron. J.* 90(5): 662-671.

Colla, G., Mitchell, J. P., Joyce, B. A., Huyck, L. M., Wallender, W. W., Temple, S. R., Hsiao, T. C., and Poudel, D. D. 2000. Soil physical properties and tomato yield and quality in alternative cropping systems. *Agron. J.* 92(5): 924-932.

Condron, L. M., Cameron, K. C., Di, H. J., Clough, T. J., Forbes, E. A., McLaren, R. G., and Silva, R. G. 2000. A comparison of soil and environmental quality under organic and conventional farming systems in New Zealand. *N. Z. J. Agric. Res*. 43(4): 443-466.

Cooper, J., Sanderson, R., Cakmak, I., Ozturk, L., Shotton, P., Carmichael, A., Haghighi, R.S., Tetard-Jones, C., Volakakis, N., Eyre, M., and Leifert, C. 2011. Effect of organic and conventional crop rotation, fertilization, and crop protection practices on metal contents in wheat (*Triticum aestivum*). *J. Agric. Food Chem.* 59(9): 4715-4724.

Coppuccino and Sheman. 1996. *Microbiology – A laboratory manual* (4th Ed). The Benjamin/ Cummings Publishing Company Inc., 213p.

da Rocha Silva, A. V. C., Araujo, J. M. A., Arruda, A. R. R., Antunes, J. E. L., and Araujo, A. S. F. 2018. Soil respiration and bulk density under organic and conventional farming systems. *Colloquium Agrariae*. 14 (4): 167-171.

de Souza Araújo, D. F., da Silva, A. M. R. B., de Andrade Lima, L. L., da Silva Vasconcelos, M. A., Andrade, S. A. C., and Sarubbo, L. A. 2014. The concentration of minerals and physicochemical contaminants in conventional and organic vegetables. *Food Control*. 44: 242-248.

Dhumgond, P., Prakash, S. S., Srinivasamurthy, C. A., and Bhaskar, S. 2017. Soil fertility status as influenced by different cropping systems in hill zone acid soils of Karnataka, India. *Int. J. Curr. Microbiol. Appl. Sci.* 6(4): 670-678.

Diouf, A. 2016. Effect of organic amendments on heavy metal distribution and uptake in vegetable gardens in Senegal. Ph.D. thesis, Virginia Tech, 123p.

Domagała-Świątkiewicz, I. and Gąstoł, M. 2013. Soil chemical properties under organic and conventional crop management systems in south Poland. *Biol. Agric. Hortic.* 29(1): 12–28.

Doran, J.W. and Parkin, T.B. 1994. Defining and assessing soil quality. In: Doran, J.W. (ed.), *Defining Soil Quality for a sustainable environment*. Soil Science Society, Amer. Special Pub.35, Madison, WI, pp. 3-21.

dos Santos, L. A. O., Naranjo-Guevara, N., and Fernandes, O. A. 2017. Diversity and abundance of edaphic arthropods associated with conventional and organic sugarcane crops in Brazil. *Fla. Entomologist*. 100(1): 134-145.

Dotse, C. K. 2010. Assessing commercial organic and conventionally grown vegetables by monitoring selected heavy metals found in them. M.Sc. Chemistry thesis, East Tennessee State University, United states, 1715p.

Drinkwater, L. E., Letourneau, D. K., Workneh, F. A. C. H., van Bruggen, A. H. C., and Shennan, C. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecol. Appl.* 5(4): 1098-1112.

Eghball, B. 2002. Soil properties as influenced by phosphorus-and nitrogen-based manure and compost applications. *Agron. J.* 94: 128–135.

Everson, R.J. 1975. A modification in the official methods for the determination of metals in feeds and fertilizers by atomic absorption spectrophotometry. *J. AOAC*. 58: 158.

Fang, C. and Moncrieff, J. B. 2005. The variation of soil microbial respiration with depth in relation to soil carbon composition. *Plant Soil*. 268(1): 243-253.

Fliessbach, A. and Mäder, P. 2000. Microbial biomass and size-density fractions differ between soils of organic and conventional agricultural systems. *Soil Biol. Biochem.* 32(6): 757-768.

Fu, B., Chen, L., Ma, K., Zhou, H., and Wang, J. 2000. The relationships between land use and soil conditions in the hilly area of the loess plateau in northern Shaanxi, China. *Catena*. 39(1): 69-78.

Głodowska, M. and Krawczyk, J. 2017. Heavy metals concentration in conventionally and organically grown vegetables. *Qual. Assurance Saf. Crops Foods*. 9(4): 497-503.

Gosling, P. and Shepherd, M. 2002. Theory and reality of organic soil fertility-organic matter. In *Proceedings of the UK Organic Research 2002 Conference*, Organic Centre Wales, Institute of Rural Studies, University of Wales Aberystwyth, pp. 137-138.

Gosling, P. and Shepherd, M. 2005. Long-term changes in soil fertility in organic arable farming systems in England, with particular reference to phosphorus and potassium. *Agric. Ecosyst. Environ.* 105(1-2): 425-432.

Goswami, K. and Mazumdar, I. 2014. Lead poisoning and some commonly used spices: An Indian scenario. *Int. J. Adv. Innovative Res.* 3: 433-435.

Gunapala, N. and Scow, K. M. 1998. Dynamics of soil microbial biomass and activity in conventional and organic farming systems. *Soil Biol. Biochem*. 30(6): 805-816.

Gupta, C. 1967. A simplified method for determining hot water soluble boron in podzol soils. *Soil Sci.* 103: 424-428.

Gupta, R.P. and Dakshinamoorthi, C. 1980. *Procedures for Physical Analysis of Soil and Collection of Agro- Meteorological Dates*. India Meteorological Depatment, Pune. 74p.

Hanc, A., Tlustos, P., Szákova, J., Habart, J., and Gondek, K. 2008. Direct and subsequent effect of compost and poultry manure on the bioavailability of cadmium and copper and their uptake by oat biomass. *Plant Soil Environ*. 54(7): 271-278.

Harris, R.F. and Romig, D.E. 2006. Health. In: Lal, R. (ed.), *Encyclopedia of Soil Science*. Taylor &Francis, New York, pp. 412-418.

Hathaway-Jenkins, L. J., Godwin, R. J., Pearce, B., Sakrabani, R., and Whitmore, A. 2010. A comparison between conventional and organic farming practices 1: Soil physical properties. In: *19th World Congress of Soil Science,* Brisbane, Australia, pp. 1-6.

Hesse, P. R. 1971. *A Textbook of Soil Chemical Analysis*. Chemical Publishing Company, New York, 520 p.

Ikemura, Y. and Shukla, M.K. 2009. Soil quality in organic and conventional farms of New Mexico, USA. *J. Org. Syst*. 4(1): 34-47.

Jackson, M. L. 1973. *Soil Chemical Analysis* (2nd Ed.) Prentice Hall of India Pvt. Ltd., New Delhi, India, 498p.

Jinadasa, K. B. P. N., Milham, P. J., Hawkins, C. A., Cornish, P. S., Williams, P. A., Kaldor, C. J., and Conroy, J. P. 1997. Survey of cadmium levels in vegetables and soils of Greater Sydney, Australia. *J. Environ. Qual.* 26(4): 924-933

Johnston, A. E. 1986. Soil organic matter, effects on soils and crops. *Soil Use Manag*. 2(3): 97-105.

Kaje, V. V., Sharma, D. K., Shivay, Y. S., Jat, S. L., Bhatia, A., Purakayastha, T. J., Bandyopadhyay, K. K., and Bhattacharyya, R. A. N. J. A. N. 2018. Long-term impact of organic and conventional farming on soil physical properties under rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system in north-western Indo-Gangetic plains. *Indian J. Agric. Sci*. 88(1): 107-113.

Karlen, D.L., Mausbach, M.J., Doran, J.W., Cline, R.G., Harris, R.F., and Schuman, G.E. 1997. Soil quality: a concept, definition, and framework for evaluation. *Soil Sci. Soc. Am. J.* 61(1): 4-10.

Kerala State Planning Board. 2013. *Soil Fertility Assessment and Information Management for Enhancing Crop Productivity in Kerala*. Kerala State Planning Board, Thiruvananthapuram, 514p.

Khoramnejadian, S. and Saeb, K. 2015. Accumulation and translocation of heavy metals by *Amaranthus retroflexus. J. Earth Environ. Health Sci.* 1(2): 58-60.

Killham, K. 1994. *Soil Ecology*. Cambridge University Press, Britain, 242p.

Kirckner, M. J., Wollum, A. G., and King, L. D. 1993. Soil microbial population and activities in reduced chemical input agroecosystem. *Soil Sci. Soc. Am. J.* 57: 1289–1295.

Kumar, A. 2009. Long term effect of nutrient management on soil quality and crop productivity. In: Chandra, R. and Singh, S.K. (eds), *Fundamentals* *and Management of Soil Quality*. Westville Publishing house, New Delhi, pp. 251-267.

Kumar, D.T.V. 2017. Evaluation of fortified humic acids from grow bag mixtures as phytotonic in okra. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 154p.

Larson, W.E. and Pierce, F.J. 1991. Conservation and enhancement of soil quality. In: *Evaluation for sustainable land management in the developing world: proceedings of the International Workshop on Evaluation for Sustainable Land Management in the Developing World,* 15-21 September 1991, Chiang Rai, Thailand. International Board for Soil Research and Management, Bangkok, Thailand, pp. 175-203.

Lei, W., Jing, Y., Yun-guan, X., Qiu-hui, C., Kui-yang, Y., Gang, L., Chi, Z., Wei, T., Hong-qi, Z., Xu, L., and Ji-bing, Z. 2017. Assessment of quality of soils under organic farming in South China. *J. Ecol. Rural Environ*. 33(6): 564-570.

Leifeld, J. and Fuhrer, J. 2010. Organic farming and soil carbon sequestration: what do we really know about the benefits? *Ambio*. 39(8): 585-599.

Liebig, M. A. and Doran, J. W. 1999. Impact of organic production practices on soil quality indicators. *J. Environ. Qual*. 28(5): 1601-1609.

Lipoth, S. L. and Schoenau, J. J. 2007. Copper, zinc, and cadmium accumulation in two prairie soils and crops as influenced by repeated applications of manure. *J. Plant Nutr. Soil Sci.* 170: 378–386.

Liu, B., Tu, C., Hu, S., Gumpertz, M., and Ristaino, J. B. 2007. Effect of organic, sustainable, and conventional management strategies in grower fields on soil physical, chemical, and biological factors and the incidence of Southern blight. *Appl. Soil Ecol*. 37(3): 202-214.

Mader, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Sci.* 296(5573): 1694-1697.

Malmauret, L., Parent-Massin, D., Hardy, J.L., and Verger, P. 2002. Contaminants in organic and conventional foodstuffs in France. *Food Addit. Contaminants*. 19(6): 524-532.

Marinari, S., Mancinelli, R., Campiglia, E., and Grego, S. 2006. Chemical and biological indicators of soil quality in organic and conventional farming systems in Central Italy. *Ecol. Indicators*. 6(4): 701-711.

Martin, J. A. R., Arias, M. L., and Corbi, J. M. G. 2006. Heavy metals contents in agricultural topsoils in the Ebro basin (Spain). Application of the multivariate geostatistical methods to study spatial variations. *Environ. Pollut*. 144(3): 1001–1012.

Martin, J. P. 1950. Use of acid, rose bengal, and streptomycin in the plate method for estimation soil fungi. *Soil Sci.* 69: 215-232.

Massoumi, A. and Cornfield, A. H. 1963. A rapid method for determining sulphate in water extracts of soils. *Analyst*. 88: 321–322.

Mathew, U. 1999. Status and impact of heavy metals in selected soils and crops of Kerala. Ph.D thesis, Kerala Agricultural University, Thrissur, 208p.

Mathew, U., Beena, C., and Balachandran, P. V. 2000. Forty years of permanent manorial trial in rice. *Kalpadhenu* 27(3): 14-15.

Mortvedt, J.J. 1995. Heavy metal contaminants in inorganic and organic fertilizers. *Fertil. Res*. 43(1-3): 55-61.

Nair, K.M., Kumar, S., Kutty N.M.C., Prasanna, R., Balachandran, P.V., Premachandran, P.N., and Vadivelu, S. 2007. Evaluation of soil fertility in Palakkad. In: Jayakumar, K. (ed.), *Proceedings of the National Workshop on Fertility Evaluation for Soil Health Enhancement,* 11-13 September

2007, Thiruvananthapuram. Soil Survey Organisation Agriculture (S.C. Unit) Department, Government of Kerala, pp. 111-123.

Nicholson, F. A., Smith, S. R., Alloway, B. J., Carlton-Smith, C., and Chambers, B. J. 2003. An inventory of heavy metals inputs to agricultural soils in England and Wales. *Sci. Total Environ.* 311(1–3): 205–219.

Oluwatosin, G. A., Adeoyolanu, O. D., Ojo, A. O., Are, K. S., Dauda, T. O., and Aduramigba-Modupe, V. O. 2009. Heavy metal uptake and accumulation by edible leafy vegetable (*Amaranthus hybridus* L.) grown on urban valley bottom soils in southwestern Nigeria. *Soil Sediment Contam.* 19(1): 1-20.

Ozlu, E. and Kumar, S. 2018. Response of soil organic carbon, pH, electrical conductivity, and water stable aggregates to long-term annual manure and inorganic fertilizer. *Soil Sci. Soc. Am. J.* 82(5): 1243-1251.

Padmavathy, A. and Poyyamoli, G., 2011. Effects of conventional and organic management strategies on soil quality and Biodiversity in Agricultural fields of Bahour, Puducherry, India. *Am. Eur. J. Agric. Environ. Sci.* 10(4): 644-652.

Palumbo, B., Angelone, M., Bellanca, A., Dazzi, C., Hauser, S., Neri, R., and Wilson, J. 2000. Influence of inheritance and pedogenesis on heavy metal distribution in soils of Sicily, Italy. *Geoderma.* 95(3-4): 247-266.

Pandey, J. and Pandey, U. 2009. Accumulation of heavy metals in dietary vegetables and cultivated soil horizon in organic farming system in relation to atmospheric deposition in a seasonally dry tropical region of India. *Environ. Monitoring Assess.* 148: 61–74.

Panwar, N.R., Ramesh, P., Singh, A.B., and Ramana, S. 2010. Influence of organic, chemical, and integrated management practices on soil organic carbon and soil nutrient status under semi-arid tropical conditions in central India. *Commun. Soil Sci. Plant Anal.* 41(9): 1073-1083.

Park, J. H., Lamb, D., Paneerselvam, P., Choppala, G., Bolan, N., and Chung, J. W. 2010. Role of organic amendments on enhanced bioremediation of heavy metal (loid) contaminated soils. *J. Hazardous Mater*. 185: 549–574.

Parth, V., Murthy, N. N., and Saxena, P. R. 2011. Assessment of heavy metal contamination in soil around hazardous waste disposal sites in Hyderabad city (India): Natural and anthropogenic implications. *J. Environ. Res. Manag.* 2(2): 27-34.

Pfiffner, L. and Mader, P. 1997. Effects of biodynamic, organic and conventional production systems on earthworm populations. *Biol. Agric. Hortic*. 15(4): 2-10.

Pfiffner, L. and Niggli, U. 1996. Effects of bio-dynamic, organic and conventional farming on ground beetles (Col. Carabidae) and other epigaeic arthropods in winter wheat. *Biol. Agric. Hortic.* 12(4): 353-364.

Phillips, C. L. and Nickerson, N. 2015. Soil Respiration [on-line]. Available: https://www.sciencedirect.com/science/article/pii/B9780124095489094422 [12 June 2019].

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., and Seidel, R. 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. *Biosci*. 55(7): 573-582.

Poudel, D. D., Horwath, W. R., Lanini, W. T., Temple, S. R., and van Bruggen, A. H. C. 2002. Comparison of soil N availability and leaching potential, crop yields and weeds in organic, low-input and conventional farming systems in northern California. *Agric. Ecosyst. Environ.* 90(2): 125-137.

Pulleman, M., Jongmans, A., Marinissen, J., and Bouma, J. 2003. Effects of organic versus conventional arable farming on soil structure and organic matter dynamics in a marine loam in the Netherlands. *Soil Use Manag. 19*(2): 157-165.

Radhakrishnan, B., Ranjit Kumar, Q., Ganapathy, M. N. K., and Hudson, J. B. 2006. Effect of conventional, organic and biodynamic farming systems in tea. *J. Plant Crops* 34(3): 330–333.

Rai, N., Ashiya, P., and Rathore, D. S. 2014. Comparative study of the effect of chemical fertilizers and organic fertilizers on *Eisenia foetida*. *Intern. J. Innovative Res. Sci.* 3(5): 12991-12998.

Ramesh, P., Panwar, N.R., Singh, A.B., Ramana, S., Yadav, S.K., Shrivastava, R. and Rao, A.S., 2010. Status of organic farming in India. *Curr. Sci*. 98(9): 1190-1194.

Reganold, J. P. 1988. Comparison of soil properties as influenced by organic and conventional farming systems. *Am. J. Altern. Agric.* 3(4): 144-155.

Reganold, J. P., Palmer, A. S., Lockhart, J. C., and Macgregor, A. N. 1993. Soil quality and financial performance of biodynamic and conventional farms in New Zealand. *Sci.* 260: 344-349.

Rossi, F., Godani, F., Bertuzzi, T., Trevisan, M., Ferrari, F., and Gatti, S. 2008. Health-promoting substances and heavy metal content in tomatoes grown with different farming techniques. *Eur. J. Nutr*. 47(5): 266-269.

Shannon, D., Sen, A. M., and Johnson, D. B. 2002. A comparative study of the microbiology of soils managed under organic and conventional regimes. *Soil Use Manag.* 18: 274-283.

Sheoran, H. S., Phogat, V. K., Dahiya, R., and Gera, R. 2018. Long-term effect of organic and conventional farming practices on microbial biomass carbon, enzyme activities and microbial populations in different textured soils of Haryana state (India). *Appl. Ecol. Environ. Res*. 16(3): 3669-3689.

Sheoran, H. S., Phogat, V. K., Dahiya, R., Dhull, S., and Kakar, R. 2018. Comparative effect of organic and conventional farming practices on micronutrient content in different textured soils of Haryana, India. *Int. J. Curr. Microbiol. Appl. Sci*. 7(4): 3399-3407.

Shepherd, M., Pearce, B., Cormack, B., Philipps, L., Cuttle, S., Bhogal, A., Costigan, P., and Unwin, R. 2003. An assessment of the environmental impacts of organic farming. *Agric. Res. J.* 56(8): 78-98.

Sheppard, S.C., Sheppard, M.I., Gaudet, C., Cureton, P.M., and Wong, M.P. 1992. The development of assessment and remediation guidelines for contaminated soils, a review of the science. *Can. J. Soil Sci.* 72(4): 359-394.

Sihi, D., Dari, B., Sharma, D. K., Pathak, H., Nain, L., and Sharma, O. P. 2017. Evaluation of soil health in organic vs. conventional farming of basmati rice in north India. *J. Plant Nutr. Soil Sci.* 180(3): 389-406.

Simoni, S., Nannelli, R., Castagnoli, M., Goggioli, D., Moschini, V., Vazzana, C., Benedettelli, S., and Migliorini, P. 2013. Abundance and biodiversity of soil arthropods in one conventional and two organic fields of maize in stockless arable systems. *Redia. 96*: 37-44.

Sims, J. T. and Johnson, G. V. 1991. Micronutrient soil tests. In: Mortvedt, J. J., Cox, F. R., and Shuman, L. M. (eds), *Micronutrients in Agriculture* (2nd Ed.). Soil Science Society of America, New York, pp. 427-476.

Singh, S.K. and Ghosh, A.K. 2009. Soil quality: a general review. In: Chandra, R. and Singh, S.K. (eds), *Fundamentals and Management of Soil Quality*. Westville Publishing house, New Delhi, pp. 1-15.

Soumya, K M. 2016. Organic Agriculture in Kerala: An Evaluation of Certified Organic Spices Producers. Ph.D thesis, Cochin University of Science and Technology, 337p.

Stolze, M., Piorr, A., Häring, A., and Dabbert, S. 2000. *The Environmental Impacts of Organic Farming in Europe*. University of Hohenheim Press, Germany, 127p.

Subbiah, B. V. and Asija, L. L. K. 1956. A rapid procedure for estimation of available nitrogen in soils. *Curr. Sci*. 25: 259-260.

Suja, G. 2013. Comparison of tuber yield, nutritional quality and soil health under organic versus conventional production in tuberous vegetables. *Indian J. Agric. Sci.* 83(11): 1153-1158.

Suja, G., Sundaresan, S., John, K. S., Sreekumar, J., and Misra, R. S. 2012. Higher yield, profit and soil quality from organic farming of elephant foot yam. *Agron. Sustain. Dev*. 32(3): 755-764.

Supriyadi, Mustikaningrum, I.A., Herawati, A., Purwanto, P., and Sumani, S. 2018. Soil quality assessment in organic and non organic paddy fields in Susukan, Indonesia. *Bulgarian J. Agric. Sci*. 24(5): 777-784.

Tchernyshev, N.I., Kiselyov, E.P., and Sysoev, O.E. 2019. Bridge Agriculture as the Basis of Preserving Soiled Bioorganisms. *IOP Conf. Ser.: Earth Environ. Sci.* 272 (3): 032021. Available: https://iopscience.iop.org/article /10.1088/1755-1315/272/3/032021/pdf. [05 July 2019].

Thakur, J. K. 2014. Analytical techniques for Analysis of Soil Biological Parameters. In: ICAR short course on '*Advances in Nutrient Dynamics in Soil-Plant Atmosphere System for Improving Nutrient Use Efficiency*', 02-11 Sept 2014, Bhopal [on-line]. Available: http://www.iiss.nic.in/ publication/ICAR%20Short%20course%20manual%20211%20Sep%2020 14.pdf [08 March 2019].

Tu, C., Ristaino, J. B., and Hu, S. 2006. Soil microbial biomass and activity in organic tomato farming systems: Effects of organic inputs and straw mulching. *Soil Biol. Biochem.* 38: 247–55.

van Diepeningen, A.D., de Vos, O.J., Korthals, G.W., and van Bruggen, A.H. 2006. Effects of organic versus conventional management on chemical and biological parameters in agricultural soils. *Appl. Soil Ecol*. 31(1-2): 120-135.

Velmourougane, K. 2016. Impact of organic and conventional systems of coffee farming on soil properties and culturable microbial diversity. *Sci.* 47(3): 1-9.

Venugopal, V.K. 2007. Soil Health Management –Key to Sustainable Agriculture Production. In: Jayakumar, K. (ed.), *Proceedings of the national workshop on fertility evaluation for soil health enhancement,* 11-13 September 2007, Thiruvananthapuram. Soil Survey Organisation Agriculture (S.C. Unit) Department, Government of Kerala, pp. 1-6.

Verloo, M. and Eeckhout, M. 1990. Metals species transportation in soil: An analytical approach. *Int. J. Environ. Anal. Chem*. 39(2): 179–186.

Walkley, A. and Black, I. A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* 39: 29-38.

Wander, M. M., Traina, S. J., Stinner, B. R., and Peters, S. E. 1994. Organic and conventional management effects on biologically active soil organic matter pools. *Soil Sci. Soc. Am. J.* 58(4): 1130-1139.

Wei, B. and Yang, L. 2010. A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. *Microchem.* 94(2): 99-107.

WHO/FAO [World Health Organization/Food and Agriculture Organization]. 2007. Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission 13th Session. *Report of the Thirty Eight Session of the Codex Committee on Food Hygiene*. Houston, United States of America.

Worthington, V. 2001. Nutritional quality of organic versus conventional fruits, vegetables, and grains. *J. Altern. Complement. Med.* 7(2): 161–173.

Xiong, X., Li, Y., Li, W., Lin, C., Han, W., and Yang, M. 2010. Copper content in animal manures and potential risk of soil copper pollution with animal manure use in agriculture. *Resour. Conserv. Recycling*. 54(11): 985–990

Zaccone, C., di Caterina, R., Rotunno, T., and Quinto, M. 2010. Soil–farming system–food–health: Effect of conventional and organic fertilizers on heavy metal (Cd, Cr, Cu, Ni, Pb, Zn) content in semolina samples. *Soil Tillage Res.* 107(2): 97-105.

Appendices

Appendix I

SURVEY FORM FOR YIELD AND MANAGEMENT ASSESSMENT

College of Agriculture, Vellayani

Kerala Agricultural University

Management and yield survey form

Date:

I. BASIC DETAILS

1. Name and address of the farmer :
2. Contact number :
3. Panchayat :
4. District :

II. LAND

5. Area
   a. Organic :
   b. Conventional :
6. Soil type :
7. Topography/ slope of land :
8. Irrigation and drainage facilities - available/ not, if present specify :

III. FARM DETAILS

9. Date of start of organic farm :
10. Total period under organic farming :
11. Certification body and certification standard :
12. Crops raised in the current year (and Area) :

13. Cropping pattern in the previous years :

14. Perennial crops if any in the field, Name and age:

IV. INPUTS USED IN FARM

15. Planting material

Crop- planting material	Quantity	Place of purchase

16. Livestock maintained / FYM

Item	Number	Quantity of manure production on farm

17. Green manure crops in field

No. of plants	Crops	Leaf output

18. Other organic inputs (on-farm sources)

Inputs	Quantity produced
a. Azolla	
b. Compost	
c. Crop residues	
d. Enriched manures if any prepared	

19. Off farm sources of organic inputs

Amendments/manures/fertilizers	Quantity purchased/season	Place of purchase	Price (Rs.)
Liming material			
FYM			
Compost			
Oil cake			
Bone meal/Rock phosphate			
Enriched manures			
Other commercial preparations			
Secondary and micronutrients			
Other manures			

20. Plant protection measures adopted

V. OTHER FARM MANAGEMENT ACTIVITIES

21. Soil conservation methods adopted, if any:

22. Yield

Crop	Yield

ASSESSMENT OF SOIL HEALTH AND STATUS OF HEAVY METALS IN THE CERTIFIED ORGANIC FARMS OF KERALA

by

GREESHMA P.R.

(2017-11-022)

ABSTRACT

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695 522

KERALA, INDIA

2019

141

ABSTRACT

The study entitled "Assessment of soil health and status of heavy metals in the certified organic farms of Kerala" was conducted from 2017 to 2019. The objective of the study was to assess and compare the soil health parameters and heavy metal status of the inputs and produce of certified organic farms and conventional farms of Kerala. Samples of soil, inputs and plant produce were collected from different locations of Kerala representing Northern, Hill, Central and Southern zones. The organic farms selected for study were under NPOP certification for more than 10 years. The rate of application of manures in organic and conventional farms were 30 t ha^{-1} and 2 t ha^{-1} respectively.

The first part of investigation was conducted to comparatively evaluate the effect of organic and conventional farming on soil health, for which composite soil samples from 2 depths (0-15 cm and 15-30 cm) were collected from 10 numbers each of certified organic farms and conventional farms. The collected soil samples were analysed for physical, chemical and biological properties from which soil quality index was calculated for each sample and an in situ enumeration of earthworms and arthropods was conducted by excavating 1 m^3 soil in all the farms from where soil samples were collected. Among the physical and chemical properties analysed, available N, K, Ca, Zn and Cu at 0-15 cm depth were significantly higher in soils from organic farms than conventional farms. Bulk density was found to be lower in soils of organic farms which is a good soil quality attribute. pH was significantly lower in soils of organic farms at 0-15 cm depth. Total as well as available content of heavy metals were (Ni, Cd and Pb) were not significantly different among the organic and conventional soil samples. Unlike physical and chemical properties, all biological properties were significantly higher in soils of organic farms than conventional farms. Bacterial, fungal, actinomycetes count, earthworms, soil arthropods and dehydrogenase activity were found to be significantly higher in soils of organic farms than in conventional farms at both depths and respiratory activity was found to be significantly higher in organic farms at 0-15 cm depth. Soil quality index was calculated from various physical, chemical

and biological soil properties and the highest index (61.1 per cent) was obtained in the surface soils of hill zone under both management. However the highest soil quality index was observed only in soils of organic farms in Northern and Southern zones.

The second part of investigation was input analysis in which inputs used in organic and conventional farms, available at the time of sampling were analysed for Zn, Cu, Cd, Ni and Pb. The results revealed that except for the content of Cu in manures and fertilizers, other heavy metals were not observed to be significantly different in manures and fertilizers.

The third part of investigation was plant study, in which edible parts of 10 crops were collected from both organic and conventional farms and analysed for Zn, Cu, Cd, Ni and Pb. Except for Zn, other heavy metals were found to be very much within the limit of food safety standards. Zn was found to be high in amaranthus from both organic (96 mg kg^{-1}) and conventional (105.6 mg kg^{-1}) farms. Content of Zn in yard long bean, salad cucumber and curry leaf from organic farms (60-64 mg kg^{-1}) and was found to be just exceeding the safe limit (60 mg kg^{-1}). Zn in plants was found to be significantly affected by management practices also. A significant positive correlation have been observed between the content of Zn in plants and available Zn in soil in both conventional and organically managed soils.

From the study it may be concluded that soil quality was found to be generally high in hill zone soils compared to other zones irrespective of the management practice and in all other regions, organic farming was found to be increasing the soil quality. Heavy metals in inputs and plant produce analysed were very much within safety standards. Zn content of amaranthus in organic and conventional farms exceeded the food safety limit. A significantly higher biological properties of soils in organic farms clearly manifests the long term sustainability of organic farming in Kerala's climatic condition.